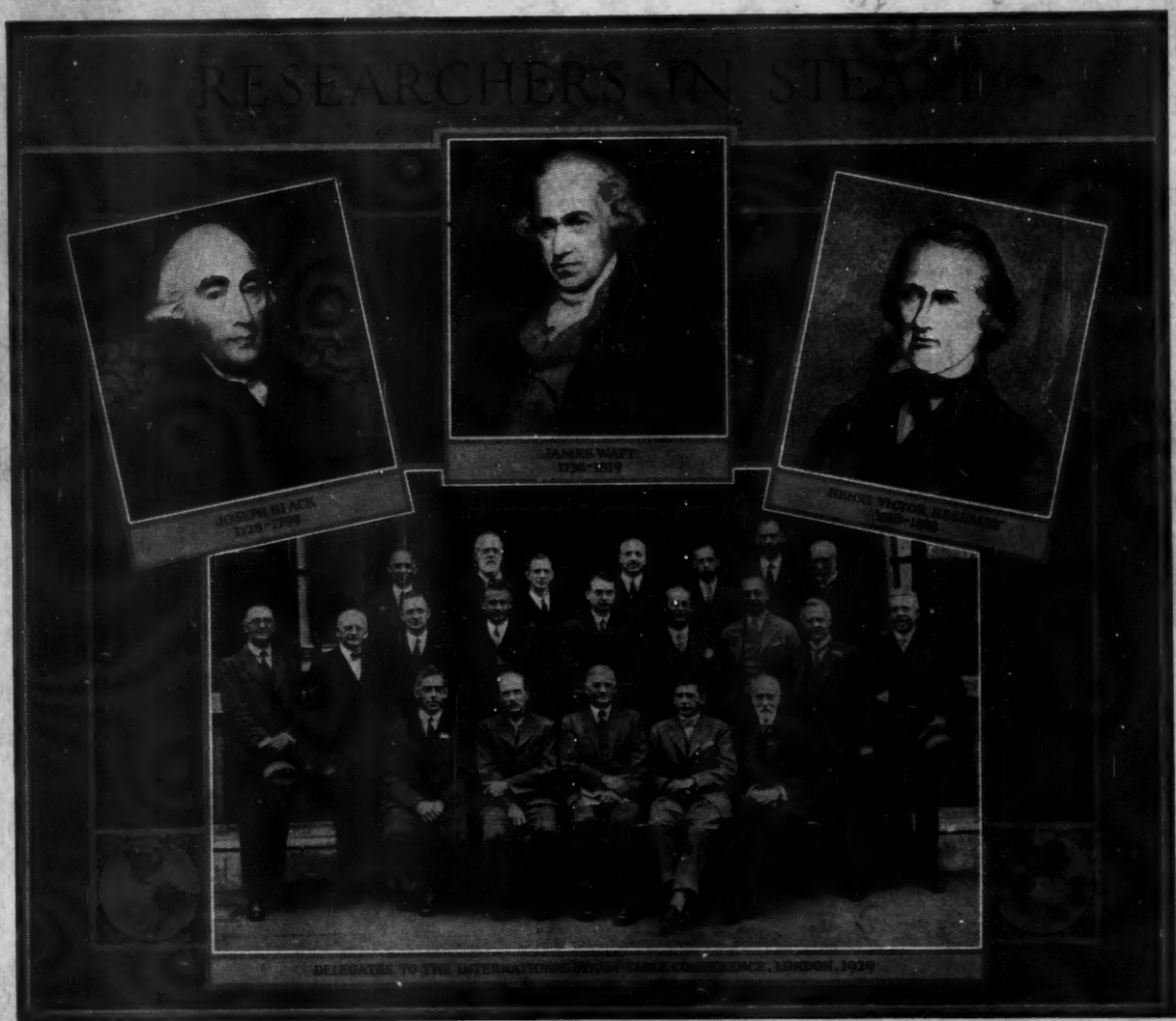
0.6
E J
no. 2

IN TWO SECTIONS—SECTION ONE

MECHANICAL ENGINEERING



THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

February 1930

Combustion Engineering Corporation in Equity Receivership . . . .

———retains its several manufacturing plants, its technical organization and its general organization as before, and is, in reality, now in a better position to carry out contracts, complete or in detail, for boiler room equipment——either big or little. It is hoped that its many friends will continue their support.

Wilfred R. Wood
Irving Trust Company } **Receivers**

Combustion Engineering Corporation

200 Madison Avenue **New York, N. Y.**

Mechanical Engineering

The Monthly Journal Published by

The American Society of Mechanical Engineers

Publication Office, 20th and Northampton Streets, Easton, Pa. Editorial and Advertising Departments at the Headquarters of the Society, 29 West Thirty-Ninth Street, New York

Volume 52 | February, 1930, Section One | Number 2

CONTENTS OF THIS ISSUE

The Engineer as Ruler ... *H. P. Vowles* ... 103
Economic Changes in 1929 ... *E. E. Hunt* ... 105
Markings on Bullets and Shells Fired From Small Arms ... *C. O. Gunther* ... 107
Progress of Fluid-Film Lubrication ... *A. G. M. Michell* ... 114
Progress in Steam Research ... 119
- Report of Technical Sub-Committee ... 119
- International Steam-Table Conference—Skeleton Steam Tables ... 120
- Report on Progress in Steam Research at M.I.T ... *L. B. Smith and F. G. Keyes* ... 123
- Vapor Pressure of Water From the Ice Point to the Critical Temperature ... *F. G. Keyes and L. B. Smith* ... 124
- Report on Progress in Steam Research at the Bureau of Standards, With Determinations of Heat Content and Latent Heat Up to 270 Deg. Cent ... *N. S. Osborne, H. F. Stimson, and E. F. Fiock* ... 127
- Comparisons ... *J. H. Keenan* ... 130
- Notes on Formulation ... *R. C. H. Heck* ... 133
- The Passing of the Mechanical Equivalent of Heat ... *E. F. Mueller* ... 139

The Economic Status of Engineers in the Federal Service ... 142
The New York Automobile Show ... 167
Synopses of A.S.M.E. Transactions Papers ... 171

DEPARTMENTAL

Survey of Engineering Progress ... 149
A Review of Attainment in Mechanical Engineering and Related Fields

Engineering and Industrial Standardization ... 161
Standardization of Electric-Motor-Frame Dimensions; A.S.A. Announcements; 1929 Supplement to "Book of A.S.T.M. Standards" Available

The Conference Table ... 162
Correspondence ... 163
Joseph's Well; Load and Stress Cycles in Gear Teeth

Editorial ... 16
Revised Index Classifications; Speeding Up Automobile Traffic; Popularization of Science; The Railroad-Merger Plan of the Interstate Commerce Commission; Fred R. Low Becomes Editor Emeritus of "Power"

Necrology ... 166
Wilfred Lewis; Sherwood F. Jeter

Book Reviews and Library Notes ... 168
Scientific Management in American Industry; Books Received in the Library

The Engineering Index ... 173

ADVERTISING

Display Advertisements ... 1
Classified List of Mechanical Equipment ... 32
Professional Engineering Service Section ... 142
Opportunity Advertisements ... 146
Alphabetical List of Advertisers ... 148

Section Two—News of Mechanical Engineering

Price 60 Cents a Copy, $5.00 a Year; to Members and Affiliates, 50 Cents a Copy, $4.00 a Year. Postage to Canada, 75 Cents Additional; to Foreign Countries, $1.50 Additional. Changes of Address should be sent to the Society Headquarters.

Entered as second-class matter at the Post Office at Easton, Pa., under the Act of March 3, 1879.
Acceptance for mailing at special rate of Postage provided for in Section 1103, Act of October 3, 1917, authorized on January, 17, 1921.

Copyrighted, 1930, by The American Society of Mechanical Engineers

C. O. GUNTHER

E. E. HUNT

R. C. H. HECK

F. G. KEYES

N. S. OSBORNE

Contributors to This Issue

Hugh P. Vowles, engineering and technical journalist and author, of London, England, was educated at Sir Thomas Rich's School in Gloucester, England, and at Elizabeth College in Guernsey, Channel Isles. During his professional career Mr. Vowles has been associated with George Waller & Sons, Stroud; Willans & Robinson, Ltd., Rugby; Gas Light & Coke Co., London; Cox & Co., London; Sun Fuel Co., Swansea; and W. H. Allen, Sons & Co., Ltd. With this latter concern he was connected from 1922 to 1928. During the war he served as works manager of the Ailsa Craig National Shell Factory, and also in airplane-factory organization work for the Air Board.

Edward Eyre Hunt, secretary of the Committee on Recent Economic Changes of the President's Conference on Unemployment, Department of Commerce, was graduated from Harvard University in 1910 with the degree of A.B. The next two years he served as an assistant in the English department of the university, and then joined the editorial staff of the *American Magazine* in New York. In 1914 he was a war correspondent in Europe, and was then for two years the American delegate of the Commission for Relief in Belgium, in charge of the Province of Antwerp. He directed the publications of the Red Cross in 1917, and the following year was the head of the economic rehabilitation work of the Red Cross in France. In 1920 he was a member of the Committee on Elimination of Waste in Industry, Federated American Engineering Societies, appointed by Herbert Hoover; secretary of the Conference on Unemployment called by President Harding in 1921, and of the U. S. Coal Commission in 1922–23.

Anthony G. M. Michell, of the Michell Crankless Engines Corporation, New York, is an Australian engineer whose academic training was started at Cambridge and completed at Melbourne. His engineering work has consisted chiefly in designing and superintending water-supply, irrigation, and hydroelectric-power undertakings in Australia.

Charles O. Gunther, professor and head of the department of mathematics at Stevens Institute of Technology, received his degree of M.E. from the Institute in 1900, joining the faculty that same year as an instructor. He was appointed to his present position in 1908. From 1912 to 1918 he served as consulting engineer with the Alphons Custodis Chimney Construction Co., New York. In 1918–19 he was with the Ordnance Department of the United States Army, in which he holds a commission as Major.

R. C. H. Heck, professor of mechanical engineering at Rutgers College, was graduated from Lehigh University with the class of 1893, and until 1908 was connected with the faculty there as instructor, assistant professor, and professor. In 1908 he accepted the chair of mechanical engineering at Rutgers.

J. H. Keenan was graduated in 1922 from the course in naval architecture and marine engineering at the Massachusetts Institute of Technology, and then entered the employ of the General Electric Co., Schenectady, N. Y., where he carried on research and development work relating particularly to steam flow.

Since September, 1928, Mr. Keenan has been on the faculty of Stevens Institute as assistant professor of mechanical engineering, where he is now engaged in instruction and research.

L. B. Smith, assistant professor of physico-chemical research, Massachusetts Institute of Technology, received his B.S. in 1918, his M.S. in 1919, and his Ph.D. in 1923, all from Massachusetts Institute of Technology. He held, respectively, the DuPont, Swett, and Savage Fellowships at M.I.T. from 1918 to 1921, and then became its research assistant and later research associate in physical chemistry.

F. G. Keyes, director of Research Laboratory of Physical Chemistry, Massachusetts Institute of Technology, received his B.S. from Rhode Island College in 1906, and his M.S. and Ph.D. from Brown University in 1907 and 1909. From 1900 to 1913 he was research associate in physical chemistry at M.I.T., and then for three years was chief engineer of the Cooper-Hewitt Electric Co. In 1916 he returned to M.I.T. as associate professor of physical chemistry research, and in 1920 was appointed director of the laboratory. Since 1922 he has also been head of the chemistry department.

N. S. Osborne, H. F. Stimson, and E. F. Fiock, who together report on the progress in steam research of the work at the Bureau of Standards, are all associated with the Bureau, Dr. Osborne being its physicist.

This Month's Cover. Joseph Black, chemist, and his friend James Watt, were among the first to investigate the thermal properties of steam. Since their day scientists and engineers, working with ever-increasing precision, have assailed this difficult research problem. Henri Victor Regnault made the first noteworthy contributions, and for years his determinations were used by designers of steam machinery.

The group shown in the photograph below these three portraits, delegates from England, Germany, Czechoslovakia, and the United States, met at London in July, 1929, for the first international conference on the properties of steam. After more than one hundred and fifty years, world-wide cooperation among researchers in steam looks toward internationally accepted steam tables. These pictures are used in connection with the papers in this issue on Steam Research.

MECHANICAL ENGINEERING

Volume 52 February, 1930 No. 2

The Engineer as Ruler

Dependence of the Modern Community on the Engineer—Architectural and Structural Undertakings of Gudea, a Sumerian Engineer-Ruler of 2600 B.C.

By HUGH P. VOWLES,[1] LONDON, ENGLAND

DISCUSSING the American Constitution in 1788, Alexander Hamilton stressed the importance of energy in the executive as a factor in good government. Nowadays, of course, energy in the executive is vastly more important than ever it was in the past. Affairs of state have become so much more complex, they change now so much more rapidly, and present such a bewildering series of unprecedented situations demanding sound judgment and quick decision, as to have passed altogether beyond the feeble executive abilities of the old-style professional politician. For this reason, among others, the election of an engineer as President of the United States is a matter of profound interest not only to America but to the whole world. In the past there has been a tendency to fill positions of high executive authority in public affairs by electing men who were more distinguished by a strong sense of continuity than by a lively realization that the reality of life lies in unceasing change. But to the engineer the idea of change comes naturally as a result of his training and experience. He, more perhaps than any other man, appreciates the truth of the saying of Heraclitus, the Ephesian philosopher, that "all things flow." And since he also is peculiarly fitted by his occupation for getting things done, it is not too much to claim that the duties of an engineer enable him also to a very special degree to tackle and solve the problems of modern statesmanship.

HEAD OF GUDEA SCULPTURED IN DIORITE

Dependence of Modern Community on the Engineer

Consider for a moment the extent to which a modern community is dependent on the engineer for its very existence. He it is who provides all the intricate and beautiful machinery which binds our civilization together. His hand and brain are everywhere, he harnesses the forces of nature, lights our cities, makes our roads and railroads, girdles the seas with ships, makes airplanes to compete in speed with the wings of the wind, and—today with sound, tomorrow with sight—is busily extending the boundaries of each man's parish to the uttermost parts of the earth. Indeed it is out of his work that most of the problems arise which governments are now called upon with increasing insistence to solve. Who, then, is more likely to approach such problems with understanding, and provide the necessary energy to insure their solution, than the engineer turned statesman? Though no doubt he will have his share of the faults common to mankind in general, he will also have the incalculable advantage of living from his youth up in a world, not of make-believe, but of things as they really are. For an engineer is primarily concerned with facts. His work is based on science; it is rooted in reality. It is, moreover, creative work, and so he is also concerned with the world of tomorrow which he is busily developing out of the world of today.

It is therefore not a little astonishing that Mr. Hoover should be the first engineer in modern times to achieve distinction as a statesman. Yet the fact remains that we have to look back across

[1] Engineering and Technical Journalist and Author. Mem. A.S.M.E.; M.I.Mech.E.

forty-five centuries before we find a man who might justly have claimed to be at once a great ruler and an accomplished engineer. It is true that his domain was tiny and his engineering empirical, but these are matters which must be judged by the standards of 2600 B.C. rather than those of today.

An Engineer-Ruler of 2600 B.C

The engineer-ruler to whom we refer was Gudea, a Sumerian "patesi" or governor of the city-state of Lagash in the country known later as Babylonia. In all probability the ancient city of Ur was also included in his dominions. It so happens that the finds of archeologists have thrown considerable light on the career of this interesting man. Several statues of him have been found which are now in the Museum of the Louvre. And though these have in each case unfortunately been decapitated, separate heads which have been identified as representing Gudea have also been found. From these it may be seen that he was clean shaven, and—as one authority expresses it—had all the appearance of being "a refined and talented man, combining firmness and determination with a total absence of anything suggestive of sensuousness."

Headless Statue of Gudea in the Louvre, Paris

(Found by de Serzac at Tello. Inscription on skirt relates to the design, building, and dedication of the temple of Ningirsu. A plan view of the stone tablet on the lap of the statue, and of the style with which the design was drawn, is shown in the bottom sketch.—Reproduced from Trans. Am. Soc. C. E., vol. 24, Jan.-June, 1891.)

Gudea became ruler over Lagash in the most troubled period of Sumerian history. The population had in recent years become very cosmopolitan and numerous reforms were found necessary. Wizards and other evil-doers were cleared out of the city. In the interests of justice new laws were framed and applied with vigor, particularly for the protection of the widow and orphan. Under his rule Lagash attained its highest point of renewed prosperity.

Gudea's Structural Undertakings

We cannot give here any very detailed account of his engineering and architectural activities. In addition to the construction and repair of irrigation canals he provided barges for water transport and constructed roads to the quarries from which he obtained local supplies of stone for structural purposes. But so far from being content with local sources, he sent caravans to trade with practically the whole known world, bringing back from remote countries gold, silver, copper, marble and variegated stones, cedar wood, and many other varieties of costly timber. Indeed, he appears to have spent almost incredible labor in his efforts to beautify and "modernize" his city. Cedar wood, boxwood, and juniper were cut and transported to the river Euphrates, and then floated down to Lagash in the form of rafts, which served also to carry supplies of stone, porphyry and marble. Gypsum and asphalt were brought by ship. It is very interesting to note from the inscriptions of his time that long sea voyages along the Arabian peninsula were even then already quite a commonplace proceeding. He also speaks of bringing stones from lands which were a whole year's journey distant. From the extent and frequency of these expeditions which he sent to secure foreign products we may realize something of the power and wealth of this ruler who scarcely ever alluded in all his writings to his political or military position.

Probably the most ambitious of Gudea's structural undertakings was the complete reconstruction and enlargement of the temple of Ningirsu. For this work he secured the finest materials obtainable. One of his statues represents him as a sitting figure with a rectangular stone tablet on his knees. On this is traced the ground plan of the temple in outline, very much as an architect or engineer would draw it today. On the outer edge is carved in relief a graduated rule, subdivided by lines into 16 digits, there being 30 digits in the Sumerian cubit, which was approximately 20 inches. There is also a representation of the style with which the design was drawn. When the temple was finished this statue was installed and a great holiday proclaimed to the people of Lagash.

The rulers of ancient Egypt retained superintending engineers and architects to draw up designs for them. So also did the emperors of Rome. But from the evidence available it seems clear that Gudea himself, energetic, competent, and resourceful, was responsible not only for the design but also for supervising the execution of his work. Evidently he was, as President Hoover is now, a man of great practical ability as well as a wise and vigorous ruler. Indeed, in spite of vast differences of time and circumstance, there are so many points of resemblance that, could they have met, one could imagine the two men shaking hands with complete accord and mutual appreciation.

Economic Changes in 1929

By EDWARD EYRE HUNT,[1] WASHINGTON, D. C.

ONE of the useful purposes served by the Hoover report on "Recent Economic Changes" is that of providing what engineers call "bench marks." We have in this report our first comprehensive study of post-war economy in the United States. We have here a national audit, a verification of the balance sheet with which you and I have been working daily for ten years past, whether as little boys and girls engaged in the important business of growing up, as youths and maidens crowding into our overstuffed colleges and universities, as mature men and women earning a livelihood, or as ancient crones and superannuated soldiers of fortune laid on the economic shelf.

Every one of us is in this report, not once, but hundreds of times. We are the consumers on whose changing habits it lays such emphasis; we make up the structure of industry which it presents as a sort of merry-go-round for our entertainment; we are construction, transportation, agriculture, marketing, labor, management, banking, and business cycles. Economic jargon may temporarily conceal us in this tremendous heap of facts, but as I look at the charts and tables which stud the printed pages, I seem to see millions and millions of little moving human shapes, smaller than Gulliver's Lilliputians, going up, down, and about in the dance of life, combining and separating to form the trends which the experts have measured for us.

Tonight I shall try to use this report simply as background and to present what information I have been able to assemble on those changes which have occurred since it appeared, picking out whatever information may now be available to supplement the material already published.

The report laid particular stress on the speed and spread of recent developments, rather than upon their novelty. It could find no evidence of a "new era," no evidence of a suspension of old and familiar economic laws. What it found was that the breadth and scale and tempo of recent developments had given them new importance.

The Committee noted that prosperity had been spotty. It noted also that higher living standards had spread with phenomenal speed; that productivity and buying power had increased; and in the balance of production and consumption it found one of the most vital factors in our economic equilibrium.

Our first test is to determine how far economic balance has been upset by the crash in the stock market in October. It is possible that one of the elements which maintained the bull market for so long a time was the inability of many men to distinguish between the stability of business on the one hand and the movement of stock prices on the other. In a large number of cases the American business man, cautious and conservative in the management of his business, was at the same time a reckless speculator on the stock exchange.

I think the conclusion must be irresistible that the state of the market for many months was a menace to economic equilibrium; that it threatened the organic balance of economic forces in this country and abroad; that it was far from flattering to our economic culture. Yet every check-up which has recently been made reveals the same set of facts. In the months since the report on "Recent Economic Changes" appeared we find the same spotty prosperity, the same large volume of production, the same high productivity and low costs, the same levels of employment, the same increases in buying power and profits, the same lack of threatening inventories or cancellations, and the same gentle decline in wholesale prices. Interest rates are lower and cash reserves are greater.

Yet we also find, I think, during the past summer, some evidences of inflation and the beginnings of a dip in the business cycle. I am not one of those who think that scores of business managers can give half their minds to the stock market and half to their business and expect business to run itself. But I point to the inescapable fact that the mass of business men must have been "sawing wood," even if some of them were playing at being bulls and bears. It is too soon to speak with certainty—our statistics necessarily lag behind the facts; but we may find that the fundamental conditions of business today are stronger as well as sounder than they were at the beginning of the year 1929.

America's Problem the Development of a Technique of Economic Balance

Marshal Foch once exclaimed, "Let history and principles go to the devil. After all, what is the problem?"

Our problem is this: to develop in this country a technique of economic balance. We are traditionally a nation of extremists with a penchant for upsetting the apple cart. Witness our vast natural resources and our wastefulness in using them; witness our phenomenally high rate of accident and crime—the highest among civilized nations; witness the extremes to which we have been accustomed to carry the swings of prosperity and depression. But in the last decade certain countervailing tendencies have been noted. Our campaigns for conservation, wiser utilization, and elimination of waste, such slogans as "safety first" and "law enforcement," and in the field of economics, the emphasis on stabilization—all these have made headway against our traditional attitudes.

Perhaps we can picture the national economy as one of the common playthings of childhood—a seesaw. In this case the seesaw is never still. Forces on both sides of the balance are always changing, so that one end of the beam is tipping a little bit up and the other a little bit down at any given moment. Yet there may be a rough equilibrium if the forces acting on the two ends of the beam are so directed as to neutralize each other. The delicate balance may be preserved if we know what the forces are and how they may be controlled.

That is the most significant thing which the Committee on Recent Economic Changes attempted to indicate in its report. We pointed out certain forces which can destroy economic balance. We listed, for example—eight months before the crash in the stock market—the withdrawal of money from industry and its use in speculation; we mentioned the waste of natural resources; we pointed to the dangers of price manipulation; we indicated the perils of a disregard of the common interest by either management or labor. Ignorance of economic principles, selfish greed, and inadequate leadership, we showed, are perennial threats to economic balance.

On the other hand, we found a hopeful sign in the rough balance between consumption and production in the post-war period—

[1] Secretary, Committee on Recent Economic Changes of the President's Conference on Unemployment, U. S. Department of Commerce. Mem. A.S.M.E.

Address delivered on Tuesday evening, December 3, 1929, at the Annual Meeting of The American Society of Mechanical Engineers, New York, N. Y.

a rough balance, it is true, but a balance none the less. A great financial editor of my acquaintance looks on this as the most extraordinary fact in our post-war economics. By all the rules of history and principles, derided by Marshal Foch, American industry should have run wild in the traditional way. It didn't. The market did, but business didn't. Here, then, is the first real test of balance.

The second test is already begun. It is the President's prompt intervention without waiting for major business troubles to develop. This intervention—or rather inspiration—is not only novel, it is revolutionary. It will take time to appreciate fully this action of the President of the United States calling into conference the representatives of business—by that I mean the whole range of business leadership from bankers to organized labor—determined to counteract the effects of a dip in the business cycle by the stimulation of private and public construction, by the maintenance of general buying power, and by the preservation of industrial peace. The inception of the task has been brilliant. The measure of its success will not become apparent for months. But if, as I hope, we are some day to have in this country a managed national economy based upon the full cooperation of industry and Government, the most important move in this direction will be found in the recent conferences in Washington.

We are far from possessing a technique of economic balance. We must know far more than we do today of the forces and of how to control them, but a sound beginning has been made. Already the swings of our economic seesaw are notably less than they were before the war. We shall never know how much more they can be controlled until we try.

General Trend of Developments in Feedwater Treatment

By SHEPPARD T. POWELL,[1] BALTIMORE, MD.

POSSIBLY the most interesting recent engineering development in feedwater treatment has been the combination of various forms of water-purification processes. The combination of chemical and zeolite softening, additions of coagulants with softening reagents, the continuous blowdown system, and steam purifiers has revolutionized feedwater treatment. This has made possible a broader field for the designing engineer than previously was considered possible.

The conditioning of feedwater is no longer limited to a single process but is a series of corrective treatments. The arrangement and extensiveness of the design will depend upon the steam-station requirements and the economy resulting from the combination treatment. Recirculation of concentrated boiler waters has been used in the past, but has not been widely employed. Recently a number of novel applications have been made which are attracting attention since they have some merit for specific conditions. In some of the designs recirculating only with heat recovery is effected, while in others partial softening also takes place.

No new chemicals of importance have been produced for water conditioning, but there has been a very marked increase in the use of certain softening reagents. This is particularly so in the case of phosphates and sodium aluminate. The increased use of the reagents is due primarily to purer products and more exact knowledge of their value for specific conditions. The investigations to determine methods of water treatment to inhibit embrittlement of boiler steel have been partially responsible for the increased use of phosphate. Both di- and tri-sodium phosphates have been used in the past. Mono-phosphate has now been offered for this service. This product has some advantage over the other sodium salts, since the desired soluble phosphate is obtained with a lesser concentration of the sodium radical.

Inhibition of corrosion of boilers, heaters, and condensers by electrolytic methods has continued to attract attention, and a number of successful installations has been made during the past few months. Research work has been carried on in at least two universities in an effort to determine the cause of this phenomenon. A number of theories have been advanced to account for this form of protection, but experimental data are lacking which would account for the mechanism involved in the retardation of the corrosion rate.

A number of valuable contributions to the art of industrial water treatment have been made recently. Possibly the most constructive study in reference to the mechanism of scale formation has been the work of Dr. E. P. Partridge, conducted at the University of Michigan. The data presented by this investigator have thrown new light on the deposition of scale-forming solids, and should prove of value in directing attention to future methods for controlling scale formation in evaporators and in boilers.

The recent corrosion study by Dr. R. U. Evans has added much to our knowledge of film formation and the inhibition of corrosion by this action. Although this work is not a specific study in boiler-water treatment, the scientific facts established nevertheless apply forcefully to the control of corrosion problems encountered in steam generation.

A number of extremely valuable contributions relating to embrittlement of boiler steel have been made through the Verein Deutscher Ingenieure. Likewise, the work of Thiel and Luchmann[2] on the same subject will be found instructive in revealing the viewpoint of the German investigator.

Many new problems have been encountered which may not be solved without more intimate knowledge of the chemistry of water. The presence of non-condensable gases in steam, especially carbon dioxide, has given much concern to those responsible for steam-station control. Acid steam from this source is much more frequent than is usually suspected. No solution for the control of the difficulty is at present available. The dissociation of even pure water in steel economizers and superheaters has been shown recently to be a possibility under certain conditions. The detrimental effect of such dissociation products on steel is well known and must be avoided, since the resulting damage is permanent and may be very costly. The problem may not be discussed intelligently, since much study must be given to it over a wide range of conditions before the extent and acceleration of this destructive action on steel can be determined accurately. The report to be presented by Mr. C. H. Fellows at this meeting shows the possibilities of the dissociation of water under certain conditions. One industrial concern is now conducting similar experiments at pressures up to 4000 lb.

[1] Consulting Chemical Engineer.

From a paper presented at the Annual Meeting of the American Water Works Association, Toronto, Ont., June 24 to 28, 1929.

[2] Report of Committee on Feedwater Studies of the Association of Large Boiler Manufacturers.

Markings on Bullets and Shells Fired From Small Arms[1]

A Study of the Engravings Made on the Cylindrical Portions of Bullets by the Lands and Grooves of the Bore of an Automatic Pistol, and of Breech-Block and Firing-Pin Imprints on Cartridge Cases and Primers

By CHARLES O. GUNTHER,[2] HOBOKEN, N. J.

WHETHER or not a certain "fatal bullet" was fired from a particular weapon is a question which has frequently confronted juries trying homicide cases; and what is more, there have been many cases in which the expert testimony relating to this question has been conflicting. What, then, forms the basis of such testimony? It is the purpose of this article to discuss certain matters which are involved in the answer to this question, and more specifically as these matters are exemplified in the automatic pistol, caliber .45, model of 1911, U. S. Army. A full description of this weapon will be found in "Training Regulations," No. 320–15, issued by the War Department under date of March 3, 1924.

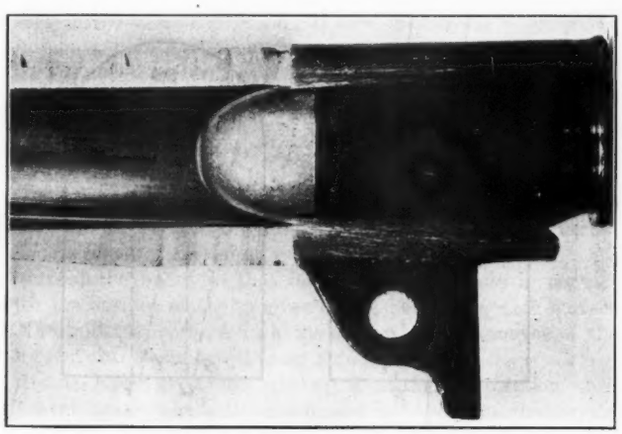


FIG. 1 SECTION OF BARREL OF AUTOMATIC PISTOL WITH A BALL CARTRIDGE IN THE CHAMBER

If it is possible to establish the identity of the weapon from which a particular bullet was fired, then every bullet, in passing through the bore of a weapon, must acquire something which will reveal, upon proper analysis, characteristics or a combination of characteristics peculiar to the bore of that weapon; and in order to establish the identity of the weapon it is necessary that these characteristics or the combination of characteristics be of such nature as to preclude their being found in the bore of any other weapon than that from which the bullet issued.

It will be shown that the surface of the cylindrical portion of the bullet is engraved by the lands and grooves as it passes through the bore of the weapon, and that it is from an analysis of this engraving that the aforesaid characteristics are to be determined.

ANALYSIS OF MOTION OF BULLET THROUGH BORE OF AUTOMATIC PISTOL

In a logical development of this subject it is first necessary to direct one's attention to the science of ballistics, and more particularly to that part called interior ballistics, which treats

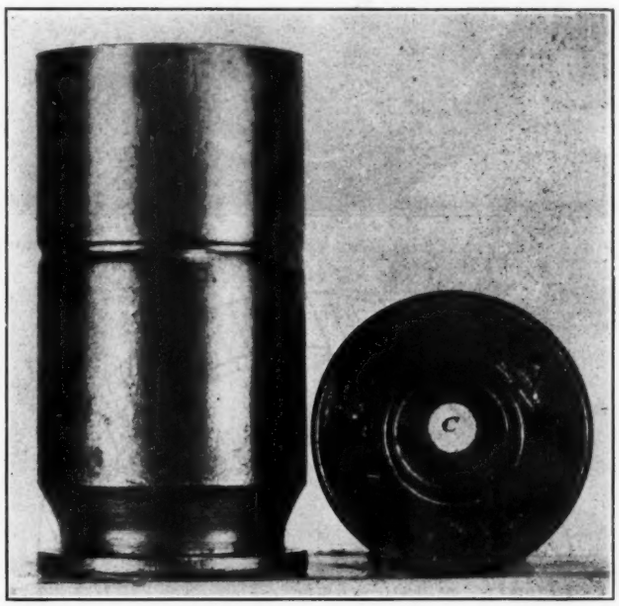


FIG. 2 CARTRIDGE CASE

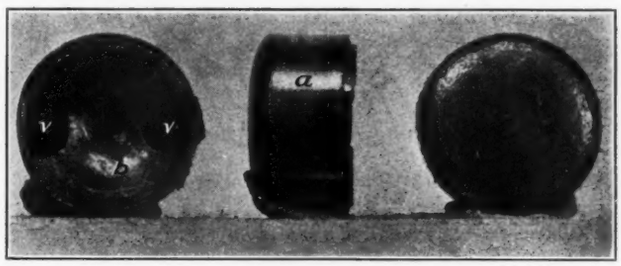


FIG. 3 PRIMER

of the motion of the projectile while still in the bore of the gun. In this connection the motion of a bullet through the bore of the automatic pistol referred to above will be analyzed.

The barrels of this pistol are interchangeable. Fig. 1 is a view of a section of a barrel with a ball cartridge in the chamber. The total length of the ball cartridge is 1.261 in., and its compo-

[1] A partial statement of results of a research being aided by Engineering Foundation.

[2] Major, Ord.-Res., U. S. A. Consulting Engineer and Professor of Mathematics, Stevens Institute of Technology. Mem. A.S.M.E.

nents consist of cartridge case, primer, powder, and bullet.

The cartridge case, Fig. 2, is 0.895 in. long and is made of brass. In the base of this cartridge case there is a small cylindrical chamber to receive the primer. This chamber is provided with a small hole *c* which communicates with the powder chamber.

The primer, Fig. 3, consists of a cup *a* made of gilding metal or some other metal that is softer than the brass of the cartridge

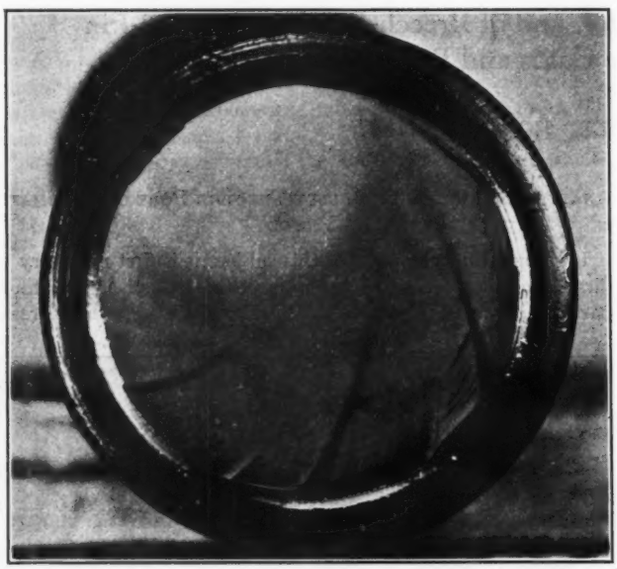


FIG. 4 VIEW LOOKING INTO THE MUZZLE OF A PISTOL BARREL

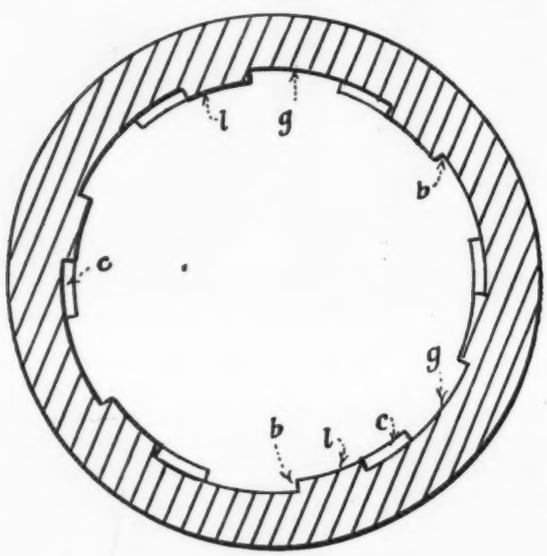


FIG. 5 CROSS-SECTION OF BARREL

case. The cup contains the primer composition against which a paper disk is tightly pressed and over which an anvil *b* is forced into the cup. The anvil is made of brass and resists the blow of the firing pin, which crushes the composition between the cup and the anvil; the flame thus produced is communicated to the charge by the two vents *v* in the anvil through the hole *c* in the base of the powder chamber.

The bullet consists of a jacket made of gilding metal or cupronickel, enclosing a core of lead and tin composition. The bullet weighs 230 ± 2 grains and has a length of 0.662 in. The cylindrical part of the bullet has a diameter of 0.45015 in. The bullet is seated in the cartridge case to a depth of 0.296 in.

The powder is a smokeless powder and the charge varies with the powder and is usually about five grains.

Fig. 4 is a view looking into the muzzle of a barrel, and Fig. 5 is a cross-section of the barrel. The barrel is 5.025 in. long. The rifling consists of six helical grooves *g* cut in the surface of the bore, which is 4.130 in. long and has a diameter of 0.445 in. The rifling is of uniform left-handed twist, making one complete turn in 16 in. The tangent of the angle of twist is equal to the ratio of the circumference of the bore to the distance to make one complete turn, or $0.445\,\pi/16 = 0.0875$, and therefore the angle of twist is approximately 5 deg. The angle of twist is analogous to the angle between a tangent to a helix of uniform pitch at any point and the axis of the cylinder upon which the helix is described. The grooves are 0.1522 in. wide and 0.003 in. deep. The lands *l* are 0.072 in. wide. The rifling causes the bullet to rotate about its longer axis (axis of symmetry) as it passes through the bore, and thus insures the necessary stability in its flight.

The right-hand side *c* of the bottom land, or the corresponding side of any other land, is called the "land shoulder," and is the side of the land which, for reasons to be considered later, is subject to erosion. The left-hand side *b* of the bottom land, or the corresponding side of any other land, is the pressure side and is called the "carry shoulder" or "driving edge" of the land. On account of the reflection of light this side of the land appears in the photograph to be beveled, whereas it is actually the same as the right-hand side.

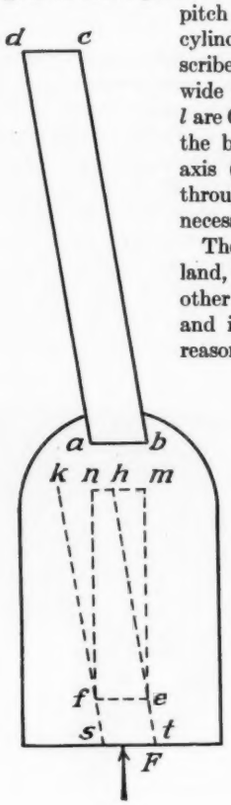


FIG. 6

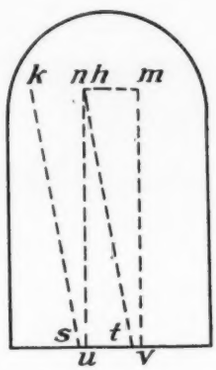


FIG. 7

Before it becomes possible for the bullet to take up this motion of rotation about its longer axis, its cylindrical part must be provided with grooves into which the corresponding lands of the bore will fit. The formation of these grooves when the bullet is driven slowly through the bore by mechanical means will be first considered.

The diameter of the cylindrical part of the bullet (0.45015 in.) is larger than the bore diameter (0.445 in.) and smaller than the groove diameter (0.451 in.) of the bore; therefore, when a bullet is forced into the bore for a short distance by mechanical means, it will jam and be subjected to radial compressive forces which tend to imbed the lands in the surface of the bullet, decrease the diameter of the bullet across opposite lands of the bore, and increase its diameter across opposite grooves of the bore.

When the force acting on the base of the bullet is removed there is also a tendency for the bullet to increase in length on account of the radial compression.

Under ideal conditions the radial compressive forces will so deform the bullet that in its deformed state it will conform to the contour of the cross-section of the bore and thus seal the bore and prevent the escape of powder gases. It is important to note that while the bullet is undergoing this deformation, its surface is subjected to the scraping action of the ends of the lands at the breech end of the bore, the plowing action of the driving edges of the lands, and the abrasive action of the surface of both lands and grooves. The engraving of the surface of the bullet is therefore the combined results of all these actions.

In the diagram, Fig. 6, let *abcd* represent a land of the bore and *F* a force acting in a direction normal to the base of the bullet. The force *F* in pounds is equal to the product of the intensity of the pressure per square inch and the area of the base of the bullet, the latter being approximately 0.16 sq. in. Initially the motion of the bullet is one of pure translation along the axis of the bore. As the bullet moves forward in the bore under the action of the force *F*, the end *ab* of the land first comes in contact with the surface of the bullet at *nm*. When the end of the land *ab* has reached the position *fe*, the point *a* will have described the line *nf* and the point *b* the line *me*, and the end of the land *ab* will have scraped the surface of the bullet over the area *nmef*. The lines *nf* and *me* will be parallel to the axis of the bore. The driving edge of the land will be in the position *kf*, and the area *nfk* will have been subjected to the plowing action of the driving edge *ad*. If now the driving edges of the lands have imbedded themselves in the bullet to such a depth that the metal in contact with them is sufficient to withstand the tangential force exerted by them through the force *F*, the bullet will take up a motion of rotation and the end of the land *ab* will scrape the area *fets* as the bullet continues its motion. The surface of the bullet is therefore no longer subjected to the scraping action of the ends of the lands after the base of the bullet has passed into the bore, but only to the abrasive action of the surface of the lands. When the radial compression has deformed the bullet so that its surface also comes in contact with the surface of the grooves of the bore, then such surface of the bullet in contact with the surface of the grooves of the bore will also be subjected to an abrasive action.

If the bullet does not take up a motion of rotation until after the base of the bullet has passed into the bore, the driving edge of the land may occupy the position *ks* in the diagram, Fig. 7, and the land shoulder the position *ht*. While there is always a tendency for the driving edge of the land to imbed itself in the surface of the bullet and thus prevent the escape of powder gases along *ad*, Fig. 6, the same is not true for the land shoulder. If the bullet does not take up a motion of rotation until after the base of the bullet has entered the bore as shown in Fig. 7, powder gases will escape at *tv* along the area *thmv*, and it is this escape of powder gases under high pressure and temperature that causes the erosion along the land shoulder previously mentioned.

It is of utmost importance to note that the relative positions of the areas *htsk* and *metsfn* in Fig. 6, and the areas *htsk* and *mvun* in Fig. 7, depend upon the position of the end of the land *ab* with reference to the bullet at the instant that the latter takes up the motion of rotation. The area *htsk* represents the area of the surface of the groove formed in the surface of the bullet to receive the corresponding land of the bore, and the area *metsfn*, Fig. 6, or the area *mvun*, Fig. 7, represents the area of the surface of the bullet that has been subjected to the scraping action of the ends of the lands *ab*.

Fig. 8 is an enlargement of a photograph of the surface of a bullet corresponding to the areas referred to in Figs. 6 and 7. The breech end of one of the lands of the barrel from which this bullet was fired has a number of tiny teeth which produce the lines shown in the photograph that are parallel to the axis of the bore.[3] This can be verified without firing a bullet through the barrel; it is only necessary to force a bullet into the breech end of the barrel until the base of the bullet is flush with the breech end of the lands and then force it out of the same end.

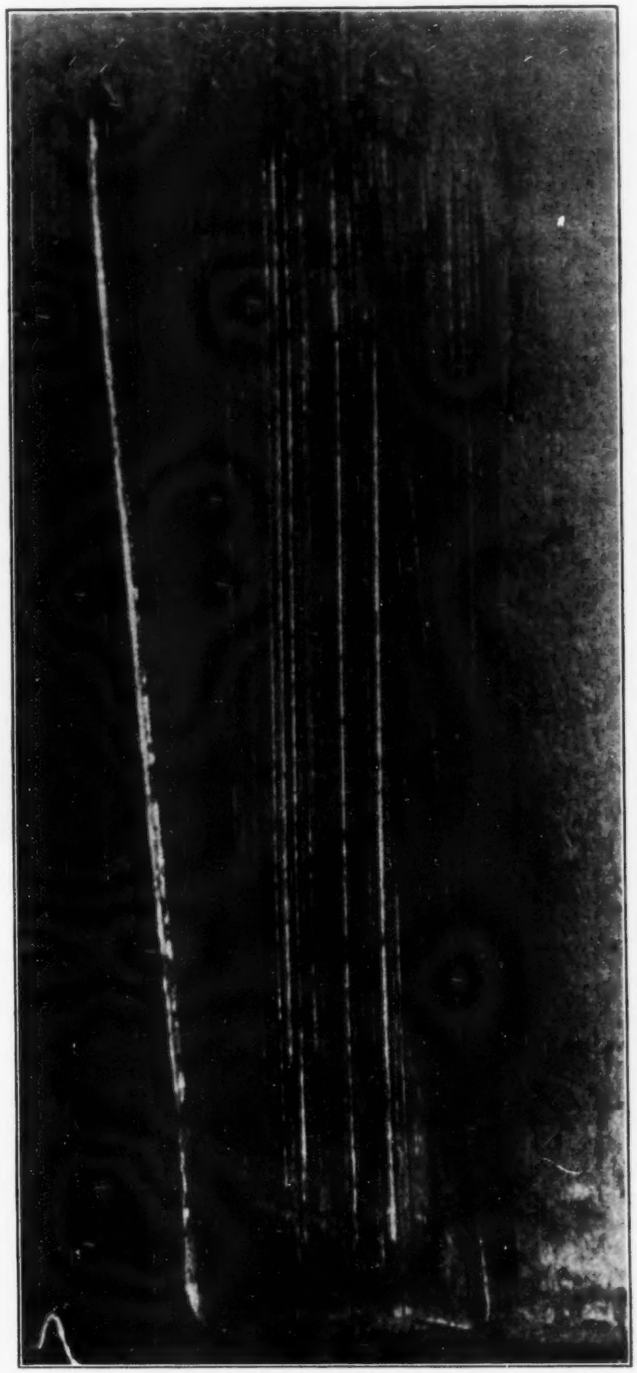


FIG. 8 ENLARGEMENT OF PHOTOGRAPH OF SURFACE OF BULLET CORRESPONDING TO AREAS REFERRED TO IN FIGS. 6 AND 7

[3] If a lead bullet is fired in this barrel, these lines may be entirely "wiped out" by the surface of the land.

An examination of the engraving of the surface of this bullet will reveal all lines made by tiny teeth which may be found at the breech end of the lands or the edge *ab* in Fig. 6.

FORCE REQUIRED TO DRIVE BULLET THROUGH BORE

To obtain some idea of the magnitude of the force *F*, experiments were made at the Carnegie Laboratory of Engineering, Stevens Institute of Technology, in which bullets were slowly driven through the bore and the resistance encountered was measured in a testing machine. In one of these tests a bullet was slowly driven through the bore of a barrel, a short distance at a time. The bullet was of Frankford Arsenal manufacture with a jacket of gilding metal. The barrel was one that had been used considerably and the bore showed signs of erosion. The force necessary to drive the bullet through the bore was initially 230 lb. (1437 lb. per sq. in.). From this it gradually increased to 350 lb. (2187 lb. per sq. in.), and then gradually decreased to 214 lb. (1337 lb. per sq. in.) when the point of the bullet was 1.5 in. from the muzzle. From this point the force again increased to 300 lb. (1875 lb. per sq. in.) at the muzzle. The greatest decrease in the driving force took place while the bullet was in the area of the bore which had been subject to erosion. The results of the tests also indicate that the resistance decreases somewhat as the speed of the bullet increases. There are a number of factors which govern the resistance encountered in driving a bullet through the bore. These will be considered later.

We shall now consider what occurs when a bullet is driven through the bore of the pistol by the force of the expansion of the powder gases. After the charge is ignited the powder burns and produces a large volume of gas. As soon as the expansive force of the powder gases is sufficient to overcome the friction of the wall of the cartridge case, the bullet will move forward in the bore, and after it has moved forward about 0.07 in. it comes in contact with the ends of the lands. The maximum pressure developed in the barrel is between 12,000 and 14,000 lb. per sq. in., and hence the maximum driving force is between 1920 and 2240 lb. The bullet passes through the bore in approximately 0.001 sec. and leaves the muzzle with a velocity of 802 ft. per sec.; its kinetic energy upon leaving the muzzle is therefore 329 ft-lb. Since the twist of the rifling makes one complete turn in 16 in., the bullet will rotate at the rate of $802 \times 12/16 = 601.5$ turns per second or 36,090 turns per minute at the instant it leaves the muzzle.

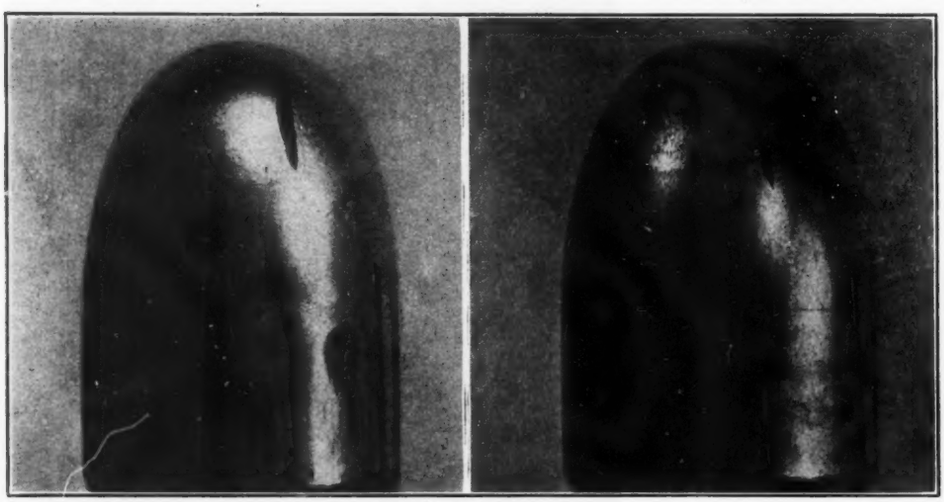


FIG. 9 CORRESPONDING SURFACES OF TWO BULLETS FIRED IN SUCCESSION FROM THE SAME BARREL

The average length of the grooves formed in the surface of the bullet is about 0.30 in. Under normal conditions it is found that the distance *km* in Figs. 6 and 7 is wider when a bullet is driven through the bore at high velocity by the force of the expansion of the powder gases than when driven slowly by mechanical means, which indicates that in the latter case there is less "stripping" and the bullet takes up the motion of rotation sooner. The distance *km* increases as the barrel becomes worn and eroded.

One might suppose that all bullets fired from this type of pistol would present very much the same appearance for the reason that the components of both pistol and ammunition are manufactured in accordance with standard drawings and specifications; but that such is not the case is illustrated in Fig. 9, which shows the corresponding surfaces of two bullets fired in succession from the same barrel. In each bullet the groove shown was formed by the same land of the bore. The cartridges were taken at random from a box of ammunition, the wartime product of an American manufacturer, and a small cut was made in the surface of each bullet near the point in order to identify its position in the bore at the instant of firing. The bullets were fired into a basket filled (not packed) to a depth of about 30 in. with soft cotton waste, from which they were readily recovered. When firing into cotton waste for the purpose of recovering bullets, the muzzle of the pistol should be held within an inch of the cotton waste.

While it is true that the components of both pistol and ammunition are manufactured in accordance with standard drawings and specifications, it is also true that the dimensions of the various components are subject to variations; such allowable variations are indicated by the "tolerances," and so we shall find that any barrel when subjected to precision measurements will show variations in bore and groove diameters as well as in land and groove widths. The barrel in Fig. 4 is of Springfield Armory manufacture; the bore diameter measures 0.4449 in. at the muzzle; at 1 in. from the muzzle the diameter is 0.4447 in., and this dimension continues to the breech without change.

Similarly bullets with show variations in size and weight, and in many bullets the cross-section of the cylindrical part will be found to be slightly oval instead of circular. The difference in the appearance of the two bullets in Fig. 9 is accounted for by the fact that the bullet on the right is undersized; the black area is the result of the action of the powder gases escaping under high pressure and temperature.

CHARACTERISTICS PECULIAR TO BORE BY WHICH BULLET FIRED THROUGH IT CAN BE IDENTIFIED

It is quite evident that a bullet undergoes a deformation as it passes through the bore of the pistol, and it is in the results of the various actions involved in producing this deformation or engraving that we must look for the characteristics or combination of characteristics peculiar to the bore by which it can be identified. The results of these various actions will depend in a large degree upon the character of the surfaces in the bore with which the surface of the bullet comes in contact, and the character

of the surfaces in a new barrel will in turn depend upon the machining operations used in its production.

In this connection we note that every metallic surface that has been produced by a machining operation, such as turning, drilling, reaming, etc., will reveal tool marks characteristic of the operation when examined under a microscope; and these marks indicate the relative motion of the cutting tool with respect to the surface. In many instances these marks are very pronounced and visible to the naked eye.

If we examine the surface of the bore of a new barrel we shall find circumferential scratches on the surface of the lands, the result of the drilling and reaming operations. The grooves are formed by a cutter which scrapes the surface as it moves in a direction parallel to the axis of the bore while the barrel is rotated at a uniform rate of one-sixteenth of one turn for each inch of travel of the cutter. As a result of this operation the surfaces of the grooves reveal striations parallel to the lands.

The circumferential scratches near the muzzle on the surface of the two lower lands and the striations on the surface of the two lower grooves at the muzzle are distinctly seen in Fig. 4, although the photograph shows the muzzle of the barrel magnified only 5.5 times.

The character of the surface of the bore and the variations in the diameters will change as the barrel becomes worn and is subjected to the erosive action of the powder gases and to the action of rust and primer fouling. When the ammunition is loaded with semi-smokeless or black powder, powder fouling must also be considered.

A complete analysis of the deformation that the bullet undergoes as it passes through the bore of the pistol may therefore be divided into two parts: the first dealing with the formation of grooves in the surface of the bullet, and the second with marks and scratches that the surface of the bullet reveals on account of its contact under pressure with the surface of the walls of the bore and the driving edges of the lands.

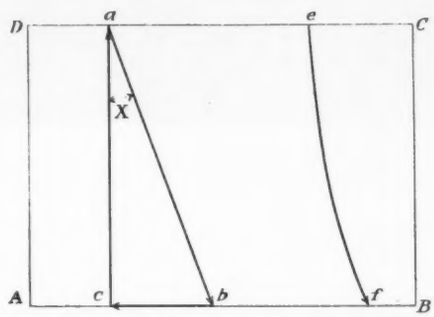


FIG. 10 DEVELOPMENT OF CYLINDRICAL SURFACE OF BULLET

When a bullet is fired from a pistol the formation of the grooves is largely dependent upon variations in the dimensions of both the bore and the bullet, to which reference has already been made. A bullet of normal size fired in a bore whose diameter is larger than normal would show an effect similar to that of an undersized bullet fired in a bore of normal diameter.

The formation of the grooves is also dependent upon the hardness of the metal of the jacket of the bullet as well as upon the position of the axis of the bullet with respect to the axis of the bore.

INTERPRETATIONS OF MARKINGS MADE ON BULLET SURFACE BY LANDS AND GROOVES OF BORE

The second part of the analysis resolves itself into an interpretation of the marks and scratches that the surface of the bullet reveals on account of its contact under pressure with the surface of the walls of the bore and the driving edges of the lands.

If there is a slight protrusion at some point in the bore, then such protrusion will scratch the surface of the bullet upon coming in contact with it as it passes through the bore, and the shape of the scratch will depend upon the relative motion of the bullet with reference to the point at which the protrusion is located.

Let us consider the convex surface of the cylindrical part of the bullet as that of a right circular cylinder. The development of this surface will be a rectangle $ABCD$, Fig. 10, in which the length of the side AB is equal to the circumference of the cylinder, and that of the side AD to its altitude. A helix of uniform pitch described on the surface of the cylinder will appear as a straight line ab in the development. If we draw ac perpendicular to AB, then ca represents the translation of the cylinder along its axis in the direction c to a, and bc represents the rotation of the cylinder about its axis in the direction b to c.

FIG. 11 VIEW OF BULLET FIRED IN BARREL SHOWN IN FIG. 4

If X represents the angle between ab and ac, then $bc/ac = \tan X$, in which X is the angle of twist previously defined.

In the development, therefore, a straight line indicates a motion of pure translation of the cylinder along its axis when $X = 0$ deg.; a motion of pure rotation of the cylinder about its axis when $X = 90$ deg.; and a helix of uniform pitch and hence a motion of translation and rotation in which the rotation is proportional to the translation, when X is greater than 0 deg. and less than 90 deg.

It follows, then, that a curved line such as ef indicates a motion of translation and rotation in which the rotation varies with the translation, in which case the angle of twist is a variable angle.

Considering the surface of the bullet and assuming the axis of symmetry of the bullet coincident with the axis of the bore as the bullet passes through the bore, then a slight protrusion at some point in the bore will produce a scratch parallel to the axis of the bullet when the motion of the bullet is one of pure translation. In this case the protrusion must be located in the bore at or very close to the breech under normal conditions.

A scratch parallel to the impression made in the surface of the bullet by a driving edge of a land of the bore indicates that the bullet was moving with a motion of translation and the full rotation provided for by the rifling, and therefore the protrusion cannot be located in the bore in the vicinity of the breech under normal conditions.

We may regard the striations in the grooves of the bore as tiny ridges and valleys running parallel to the lands, and these can only produce corresponding striations on the surface of the

bullet when the latter has a motion of translation and the full rotation provided for by the rifling; if the rotation is less than that provided for by the rifling, then these groove striations will scrape the surface of the bullet with which they come in contact. In the same way a tiny ridge in the bore parallel to the axis can only produce a scratch parallel to the axis of the bore when the bullet has a motion of translation only.

A scratch starting out in a direction parallel to the axis of the bore and then gradually changing its direction until it is parallel to the impression made by a driving edge of a land of the bore, indicates a motion of translation with an accelerating rotation and must therefore take place at the instant that the rifling takes effect; the curve *ef* in Fig. 10 illustrates the development of such a scratch; the protrusion producing it must therefore be located in the vicinity of the breech under normal conditions.

The direction of a straight line or the direction of a curve at any point is indicated by the angle X in the development, and the magnitude of this angle cannot exceed that of the angle

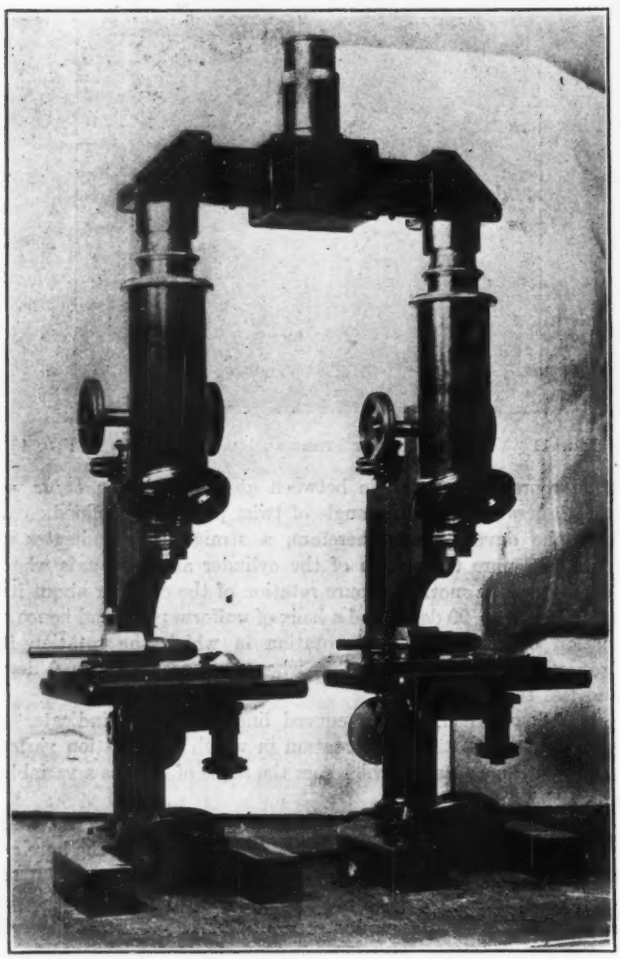


FIG. 12 TWO MICROSCOPES ARRANGED FOR COMPARING ENGRAVINGS ON BULLETS

of twist of the rifling of the bore through which the bullet subjected to this analysis has passed. In other words, if a scratch on the surface of a bullet is developed and this development indicates a direction for which the angle X exceeds the angle of twist of the bore through which the bullet passed, then such scratch was *not* produced while the bullet passed through the bore. This is of extreme importance in making an analysis of the scratches on the surface of a bullet which has met with an obstruction in its path and as a result of which it has been much deformed and its surface scratched and mutilated.

In the case of a barrel in which the rifling is of uniform right-handed twist, the point b is laid off on the line AB to the left of the point c in Fig. 10.

Following the same line of reasoning outlined above, it be-

FIG. 13 VIEW OF BREECH BLOCK OF PISTOL WITH FIRING PIN AND EXTRACTOR REMOVED

comes possible to interpret the motion of a bullet at the instant that any particular scratch was produced on its surface. If, however, a bullet were fired through a barrel in the bore of which there happened to be a loose particle of steel, then it would be a difficult matter to predict how this would affect the engraving of the surface of the bullet. On the other hand, in forming the grooves in the surface of the bullet the driving edges of the lands cut away tiny particles of metal from the jacket, and if one of these particles becomes lodged in the bore it may produce a very pronounced scratch on the surface of the next bullet fired; this scratch will probably not again appear on the surface of succeeding bullets.

The jacket of the bullet is drawn, and its surface reveals striations parallel to the axis of symmetry as a result of this operation. These striations must not be confused with scratches that the surface of the bullet receives in its passage through the bore. Fig. 11 is a view of a bullet fired in the barrel shown in Fig. 4; it shows clearly the striations resulting from the drawing operation. This bullet was manufactured in 1918 for the Ordnance Department by one of the American manufacturers of ammunition.

The surface of the bullet is scratched by the mouth of the

cartridge case in loading and in driving the bullet out of the cartridge case by the expansive force of the powder gases.

A careful study of the many manufacturing operations involved in the production of the barrel of this pistol will convince one that no two barrels will be alike down to the minutest detail. There are the variations in the dimensions of bore and groove diameters and land and groove widths which have already been mentioned, and they lead to a vast number of combinations of variations in these dimensions. But of far greater importance is the fact that the tool marks on the surfaces of the lands, grooves, and land shoulders form in any one barrel a "pattern" which will not be reproduced in its entirety in any other barrel; variations in this "pattern" will produce variations in the engraving on the surface of the bullet. The proof of this depends upon the "law of probability."

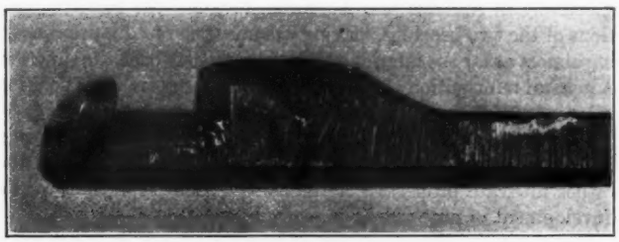


FIG. 14 EXTRACTOR

FIG. 15 FIRING PIN

Lack of space does not permit a discussion of the methods based upon the foregoing principles which are to be followed in order to determine whether or not a given "fatal" bullet was fired from a particular "suspected" weapon; suffice it to say that these methods involve a careful study of the engraving of the surfaces of bullets that have actually been fired from the "suspected" weapon and the engraving of the surface of the "fatal" bullet. These engravings are studied and compared under two microscopes connected by a comparison eyepiece (Fig. 12), both microscopes having a magnifying power of approximately 20 diameters.

IMPRINTS ON CARTRIDGE CASES AND PRIMERS

Fig. 13 is a view of the breech block of a pistol with the firing pin and the extractor removed. The surface of the breech block is formed by filing, and these file marks form a distinctive pattern which leaves its imprint on the base of the cartridge case and the primer as these are forced against the breech block by the expansive force of the powder gases, since the pressure developed by the powder gases is exerted in all directions.

The extractor, Fig. 14, will leave a mark on the side of the cartridge case near the base by which the position of the cartridge in the chamber of the barrel at the instant of firing can be determined.

The end of the firing pin, Fig. 15, will generally show one or more circumferential tool marks and irregularities which will leave their impression in the crater formed in the primer cup when the firing pin is driven into the primer by a blow from the hammer. In this pistol the firing pin can be rotated, thus making it possible to change the relative position of the firing-pin impression in the crater.

If a primed cartridge case—a cartridge from which the powder and bullet have been removed—is fired in the pistol, the pressure developed in the primer chamber in the base of the cartridge case by the ignition of the primer composition will drive the primer partly out of the case and against the breech block with a force sufficient to leave the impression of the surface of the breech block on the primer cup. The crater thus formed will not be as deep as when a fully loaded cartridge is fired.

In this pistol the empty cartridge case is ejected automatically. On account of the relatively slow action of the spring in returning the firing pin to its normal position in the rear end of the slide, the ejection of the case may take place while part of the firing pin is still protruding through the breech block, with the result that the case in the grip of the extractor will pivot on the end of the firing pin in the crater during the process of ejection, and a more or less pronounced lip will be formed at the top of the crater in the primer cup.

Fig. 16 shows the breech-block and firing-pin imprints on the cases of two cartridges that were fired in the same pistol with the firing pin shown in Fig. 15; the crater in the case on the left shows no lip, whereas the one on the right shows a very pronounced lip.

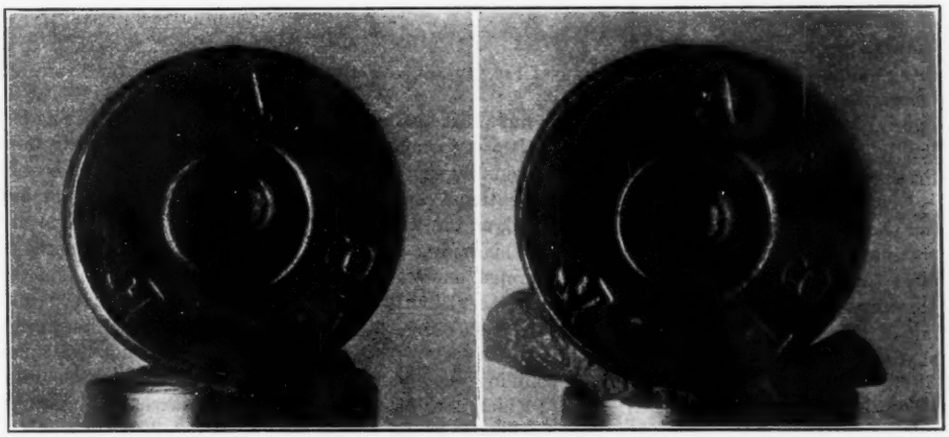


FIG. 16 BREECH-BLOCK AND FIRING-PIN IMPRINTS ON CASES OF TWO CARTRIDGES FIRED IN SAME PISTOL WITH FIRING PIN SHOWN IN FIG. 15

Thus it follows that the impression of the surface of the breech block on the base of the cartridge case and primer, the impression of the firing pin as formed in the crater in the primer, and the mark made by the extractor form a combination which makes it possible to identify a pistol when one or more of the ejected cartridge cases are available.

Progress of Fluid-Film Lubrication

By A. G. M. MICHELL,[1] NEW YORK, N. Y.

This paper discusses briefly problems of bearing design imposed by the increasing demands of modern practice, and shows how they are being met in bearings of the film-lubricated type, especially with respect to carrying high intensities of bearing pressure in journal bearings, and to increasing the durability of bearings by elimination of wear. Some commonly unrecognized factors controlling the lubrication of bearings are discussed, especially with respect to lubricants other than oil, and some new types of bearings are illustrated and described.

TO THE machine designer all bearings are only necessary evils, contributing nothing to the product or function of the machine; and any virtues they can have are only of a negative order. Their merits consist in absorbing as little power as possible, wearing out as slowly as possible, occupying as little space as possible, and costing as little as possible.

A bearing meets the last two of these desiderata in proportion as its bearing surface is diminished; or, since the load to be carried is a predetermined quantity, in proportion as the intensity of pressure on the bearing surface is increased.

Roundly speaking, therefore, progress in bearing construction consists in finding safe methods of increasing the intensity of bearing pressures. In order to do so we must not only form the bearing surfaces suitably, as the hydrodynamic theory instructs us to do, but must also provide for the supply of the lubricant which the theory postulates, and for the abstraction of whatever heat is unavoidably generated.

How far existing journal bearings of conventional construction fall short of ideal economy in space occupied, and in weight and cost, may be appreciated from Fig. 1. This shows a typical large turbo-alternator with its journal bearings, one of which is incorporated in a common casing with the adjacent journal bearing of the turbine, and with the coupling connecting the two shafts. The diameter of the shaft is 21 in.

The set of three bearings and the coupling occupy a total length of 18 ft., as compared with 14 ft., which is the length of the useful part of the alternator between its bearings. That manifest disproportion has been brought about because the designer, working on conventional lines, has not been prepared to load the bearings to more than about 60 lb. per sq. in. of the projected area of the journal surface. Still lower intensities of pressures, about 25 lb. per sq. in. of projected surface only, have continued to be the rule for many years in marine propeller-shaft journal bearings. Cylindrical-shell bearings of these classes have made little or no progress toward meeting the desiderata above mentioned since the beginning of this century. At that time it was usual to point to the then existing forms of thrust bearing as being lamentably inferior to cylindrical journal bearings in load-carrying capacity and efficiency. The constructive application of the hydrodynamic theory of lubrication to the thrust bearing by Mr. Kingsbury and the present author, working respectively in America and Australia, reversed the relative positions of the two bearings, leaving the unregenerated journal bearing almost as far the inferior as it had previously been the superior. A general reformation of journal bearings to restore their position is long overdue.

Many able papers have been written on the journal bearing, but they have been devoted rather to the investigation of the rather intricate properties of the conventional type than to the development of any new or improved type.

The most significant difference between the cylindrical bearing and the plane bearing is that while in the plane bearing the convergence of the wedge film is necessarily uniform throughout its extent, in the cylindrical bearing the same film may be converging and diverging at different points. Journal bearings in which such is the case do not effectively utilize the film theory. In the plane bearing, moreover, the surfaces necessarily come into contact over the whole of their common extent when the thickness of the wedge film is diminished to zero. In other words, both surfaces have the same, in this case, zero curvature. In the cylindrical bearing the curvatures may differ, so that contact between the surfaces, the film being removed, is upon a line only. To attain success the characteristics of the journal bearing should be assimilated to those of the successful thrust bearing. From this point of view three maxims may be stated for the construction of successful film-lubricated journal bearings. These are:

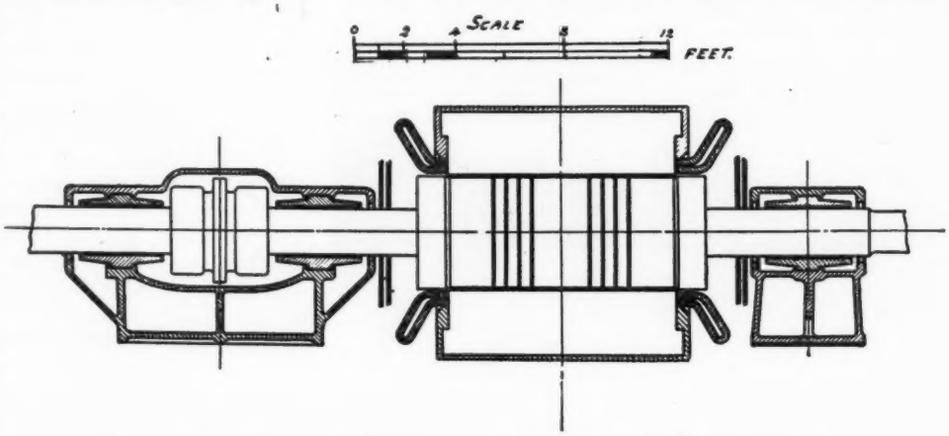


FIG. 1 JOURNAL-BEARING ARRANGEMENT OF TYPICAL LARGE TURBO-GENERATOR

GENERAL AXIOMS FOR SUCCESSFUL DESIGN OF JOURNAL BEARINGS

1 The wedge film should be wholly converging in the direction of motion of the continuous surface—that is, the journal.

2 The two surfaces should have the same curvature.

3 The discontinuous element must be pivoted, this being the only known method of producing with certainty the proper convergence of the wedge film.

A complete mathematical solution of the three-dimensional journal bearing has not yet been discovered, but a useful approxi-

[1] Michell-Crankless Engine Corp.

Presented at a meeting of the Metropolitan Section of the A.S.M.E., New York, N. Y., May 17, 1929. Abridged.

mation is obtained by assuming that the bearing is indefinitely narrow in comparison with its width. On this assumption the simple formula under Fig. 2 gives the pressure at all points of the bearing. It must be remembered, however, that the formula is not applicable to the portions of the bearing near to its leading and trailing ends.

met by arranging a series of bearing arcs, each of about 45 deg., all around the circumference. There would be, however, extreme difficulty in forming such arcs on a single bearing shell in such relationship to each other as to insure that the journal would take up a correct running position upon one of them, under all possible conditions of load.

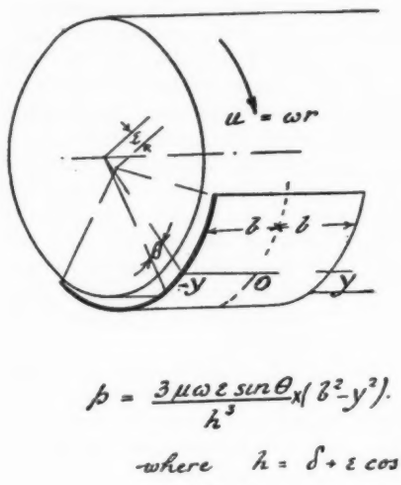


FIG. 2

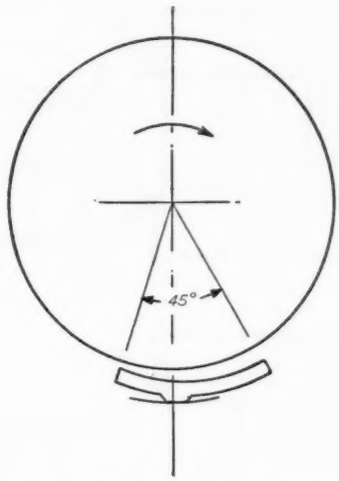


FIG. 3 PIVOTED BEARING ELEMENT

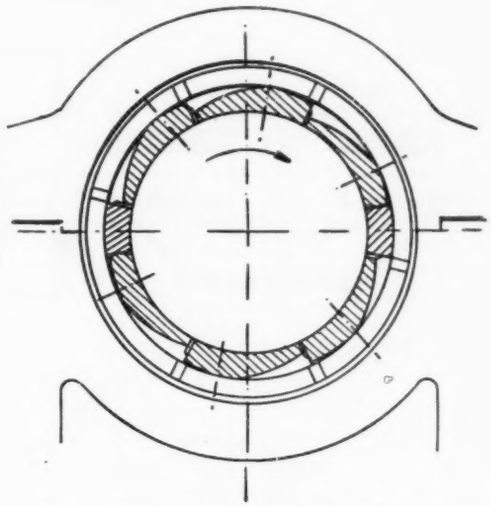


FIG. 4 JOURNAL BEARING WITH SIX PIVOTED BEARING ELEMENTS

In Fig. 2 the origin of the circumferential coordinate is at O, which is the point at which the thickness h of the film is a maximum, θ being zero at that point. The formula applies not only to the "fitted" bearing, but also to bearings in which the shell is of larger radius than the journal. An immediate conclusion which may be drawn from the formula in Fig. 2 is that the pressure p is only positive where θ is positive; that is to say, where the interspace is converging. The divergent portion of the bearing, where θ is negative, can generate only negative pressures and is therefore worse than useless since the negative pressures counteract positive pressures in the converging section in so far as their effect in supporting the load is concerned.

The second axiom, namely, that the curvature of the two surfaces should be equal, the bearing being thus what has been called a "fitted" bearing, rests mainly upon practical considerations. One of these is that to make the bearing element of equal curvature with the journal is the only generally practicable method of making its surface in *any* sufficiently accurate relationship thereto. The relation of equality is easily made and easily checked in the first instance, and easily restored by any competent mechanic. However, the most serious defect of the bearing in which the shell is of greater radius than the journal is that the effective area of the fluid film diminishes rapidly as the load on the bearing is increased, so that the maximum intensity of fluid pressure increases much more rapidly than the load. Although extremely thin films may be stable, as shown, for instance, by Stanton, the coefficients of friction in such cases are apt to be much higher than in films of normal thickness, and the danger of seizing is imminent. This point being accepted, it is at once obvious that in order to make use of any large portion of the surface of the journal, it is necessary to have more than one of such bearing arcs to carry the load.

For this arrangement there is a still more cogent reason. This is that it is very rarely in practice that the direction of loading of a journal bearing can be determined, or is in fact constant. Often the load in a given bearing may be applied in almost any direction, or successively in all directions. Such a condition can be

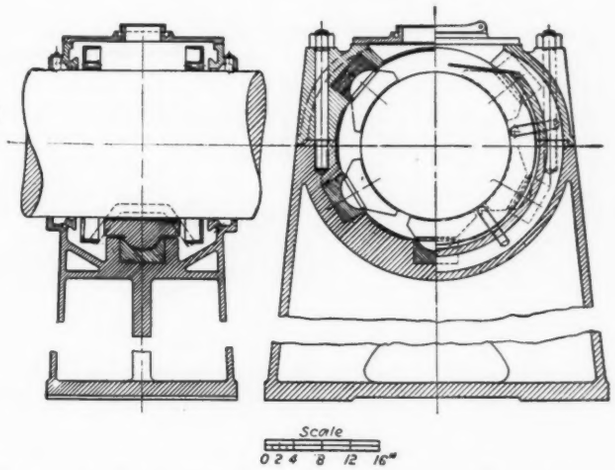


FIG. 5 AN EXAMPLE OF MULTIPLE-PAD BEARING CONSTRUCTION

The only recourse is acceptance of the third axiom, namely, that the bearing elements must be pivoted, as shown diagrammatically in Fig. 3; and Fig. 4 illustrates diagrammatically an example of the resulting construction. In this example it will be seen that six pivoted bearing elements, each subtending about 45 deg., are so arranged around the circumference that in whatever direction the journal is loaded it is efficiently supported by at least two of the elements; these being free to turn upon their pivots so as to present their working surfaces in correct relation to the journal. This advantage of the pivoted element accrues over and above its fundamental function, namely, the automatic determination of the desired distribution of load over each single element. Pivoting secures the still further advantage that overstressing of the shell element by local contact with the journal is wholly excluded, even up to the edges of the element.

A more elaborate example of the multiple-pad construction is shown in Fig. 5, which is a bearing designed for a 21-in. hori-

zontal shaft. It is indeed a bearing which could be substituted for the journal bearings of the alternator illustrated in Fig. 1 at the beginning of this paper, with the advantage of higher efficiency, greater immunity from wear, and obviously of saving in segment bearings according to Fig. 5, the resulting saving in length of the unit being $8\frac{1}{2}$ ft., and the bearings and coupling now occupying only 65 per cent of the length of the alternator instead of 125 per cent. Many such journal bearings have now been installed with success. A good many incidental difficulties not apparent at first sight, and over and above securing compliance with the essential considerations which have just been dwelt upon, have had to be elucidated and overcome. The journal bearing presents numerous peculiarities which do not arise in the thrust bearing. Nevertheless the first bearings of this type, installed in Australia in 1912, are still operating successfully, and the number and variety of successful applications is now very considerable and is continually increasing.

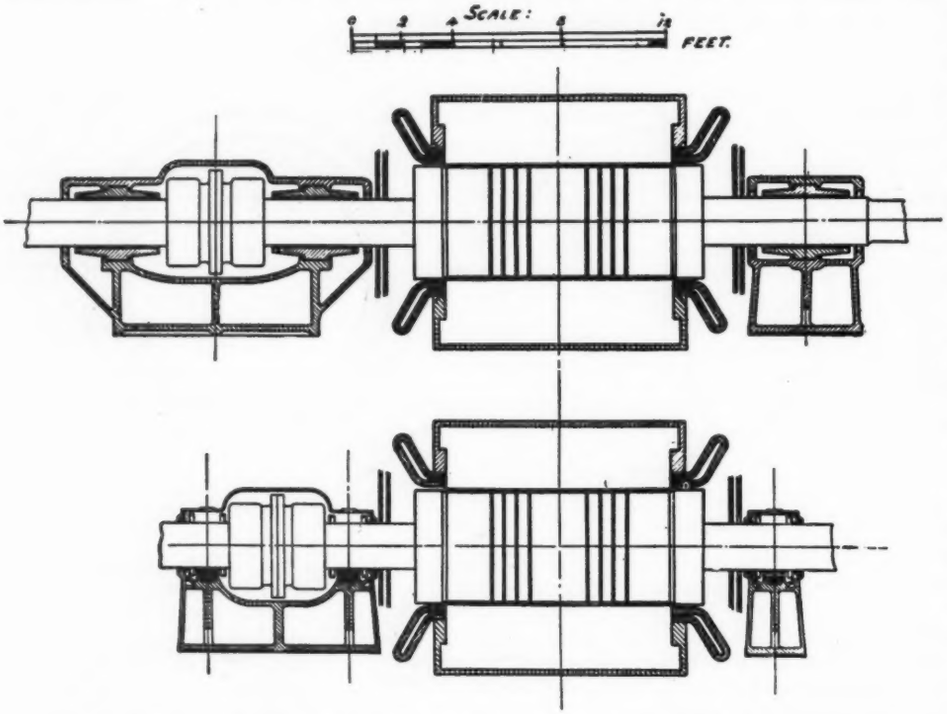


FIG. 6 SAVING IN LENGTH OF ALTERNATOR OBTAINED BY SUBSTITUTING FILM-LUBRICATED, PIVOTED-SEGMENT BEARINGS (BELOW) FOR THOSE OF THE CONVENTIONAL TYPE (ABOVE)

Fig. 7 shows a typical example of a pivoted journal bearing of the type which is now being fitted in large numbers in Europe on marine propeller shafts. The chief advantages of the type for this application, apart from increased efficiency, are that each bearing is entirely self-contained with respect to oil circulation and is practically immune from trouble due either to misalignment or to straining of the ship in a seaway. The last feature is due mainly to the fact that the bearings are equally capable of carrying forces applied by the journal upward, horizontally, or downward.

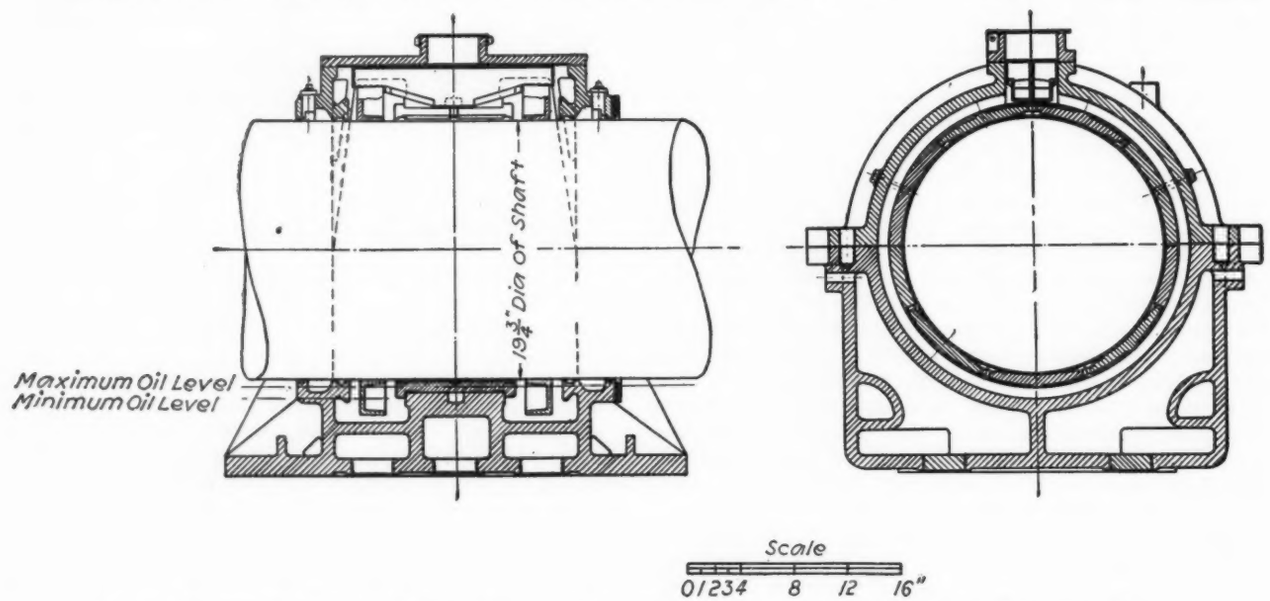


FIG. 7 TYPICAL EXAMPLE OF PIVOTED JOURNAL BEARING NOW BEING FITTED ON MARINE PROPELLER SHAFTS

space occupied. The intensity of pressure on the projected area of the journals has been raised from 60 to 220 lb. per sq. in.

AN EXAMPLE OF JOURNAL-BEARING CONSTRUCTION

In Fig. 6 the same alternator as in Fig. 1 is shown with three conventional bearings, and with three film-lubricated, pivoted-

Shaft bearings of the largest size are now being fitted by the British Navy as well as the mercantile marine, and appear to

be regarded with the same favor by seagoing engineers as the pivoted thrust bearing.

Fig. 8 shows the application of a bearing of the same type as a tunnel-shaft bearing, in one of the wing tunnels of a multiple-shaft ship. The special feature of this bearing is its adaptation to the small space available, including provision for access.

Similar bearings are used in crushing rolls for mineral treatment and in rolling and calendering machines in the paper and textile industries. For these latter applications immunity from wear is often particularly important in order that the pairs of rolls may be kept in accurate adjustment to each other when a thin material is being rolled. The high efficiency of the bearing is especially important when the process effected by the rolls requires that they should be heated by steam or otherwise. In the older type of rolls, the heat generated in the bearing, added to that conducted to it by the rolls, often produced temperatures higher than any available lubricant will endure.

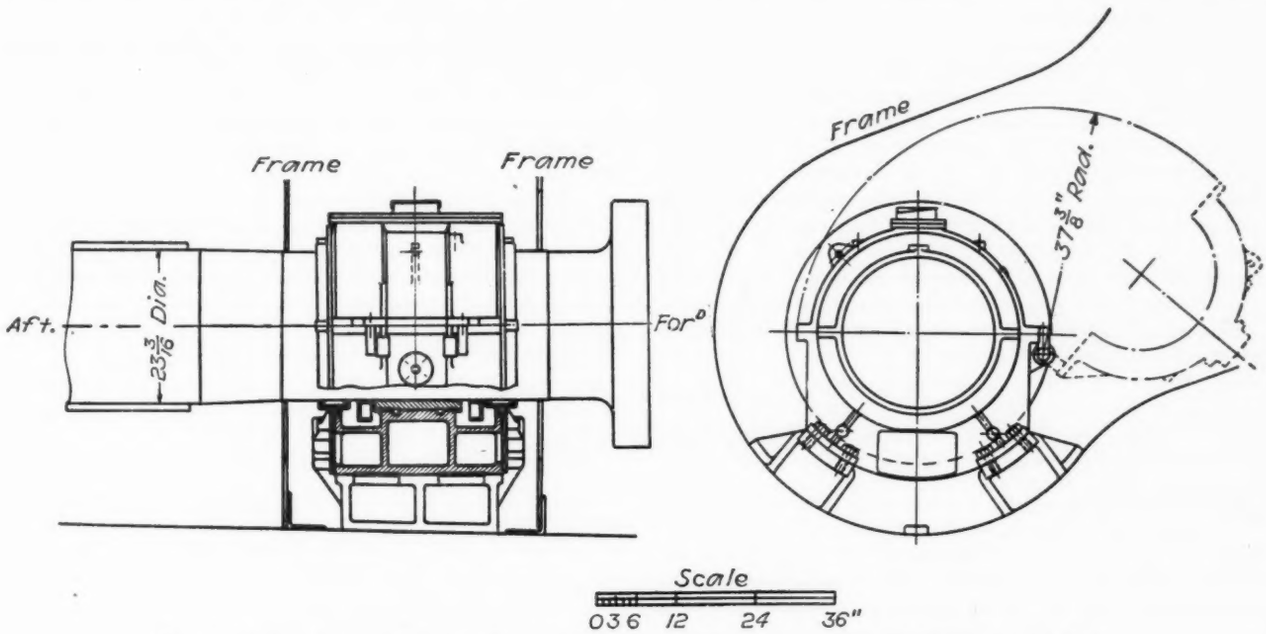


FIG. 8 APPLICATION OF PIVOTED JOURNAL BEARING IN WING TUNNEL OF A MULTIPLE-SHAFT SHIP

SOME LUBRICATION DEVELOPMENTS[2]

Following Mr. Michell's paper, Mayo D. Hersey[3] was called upon by the chairman to present informally a brief historical outline of the theory of lubrication and of the experiments on which it is based.

Mr. Hersey stated that the greater part of what he had to say would be taken from the papers listed in the Committee's bibliography, which was published as an appendix to the report entitled "Progress in Lubrication Research."[4]

The science of lubrication as we understand it today is an outgrowth of the hydrodynamic theory by Prof. Osborne Reynolds, of the Manchester College of Technology, published in 1886, and based upon the experiments of Beauchamp Tower.

The theory was extended to flat surfaces by A. G. M. Michell, the speaker of the evening, in a paper published in 1905. This solution for the first time carried the problem into three dimensions, taking proper account of side leakage, a question which has not yet been worked out mathematically for journal bearings. This was followed by Michell's development of the pivoted-segment thrust bearing. As Mr. Michell has just stated, the same type of bearing had been independently developed by Albert Kingsbury in the United States. Both inventors based their work on the theory of Osborne Reynolds.

Further British investigations by Harrison, Martin, Hardy, Stanton, Hyde, and Boswall were mentioned, as well as Petroff's work in Russia in 1883 and recent French investigations by Woog and Trillat.

German developments include the work of Sommerfeld, Gümbel, Vieweg, Duffing, Falz, Hummel, Kiesskalt, and Wolff.

Mr. Kingsbury's pioneer work on various problems dating from about 1888 and still continuing, included journal bearings, thrust bearings, cutting-tool lubrication, friction of screw threads, and oiliness of lubricating oils. Other American investigations cited were those of Howarth, Bradford, and Karelitz, as well as research on lubrication at the Massachusetts Institute of Technology and the U. S. Bureau of Standards.

Discussion[5]

E. O. WATERS.[6] The author's paper does not attempt to survey the whole field of fluid-film lubrication, but places emphasis on one specific application, namely, the use of the pivoted pad in journal bearings. The author is firmly convinced that such application is beneficial; however, it is only natural that this point of view should be accepted with some hesitancy by American engineers, whose practice has been to favor the simple journal bearing with a single fixed bearing surface.

By analyzing the equation given with Fig. 2, it can be shown that this expression for bearing pressure is derived on the assumption that the oil flow is purely axial—that is to say, the

[2] Abstract of remarks offered at the May 7, 1929, meeting of the Metropolitan Section, A.S.M.E.

[3] Chairman of A.S.M.E. Special Research Committee on Lubrication. Chief, Friction and Lubrication Section, U. S. Bureau of Standards, Washington, D. C. Mem. A.S.M.E.

[4] Trans. A.S.M.E., 1928, APM-50-4, with further discussion in MECHANICAL ENGINEERING, vol. 50, July, 1928, pp. 682–683.

[5] Abridged.

[6] Assistant Professor of Mechanical Engineering, Yale University, New Haven, Conn. Assoc-Mem. A.S.M.E.

pressure gradient in the tangential direction is considered negligible in comparison with the gradient in the axial direction. Such an assumption would hardly seem warranted unless the length and width of each pad were given extremely different dimensions.

If, as seems more plausible, it be assumed that the oil flow is tangential rather than axial, then both Howarth's and Boswall's calculations show that the plain bearing has less friction than a bearing with two or three separate pads, other things being equal, and a higher safety factor as measured by the specific clearance at the point of nearest approach. In fact, Boswall states in summarizing the calculations above referred to, that there seems to be no advantage in merely subdividing the original bearing surface into parts, but that the real merit of the multiple type must rather be attributed to the greater ease of fitting short surfaces to a shaft, and the fact that the pressure film forms more perfectly with curved surfaces if the arc of contact is kept as small as possible.

S. J. NEEDS.[7] Referring to the author's pressure equation which he offers for the use of believers in single-surface journal bearings but which he apparently cannot use himself for his pads, this equation is approximate only for very narrow surfaces, and its range of usefulness depends upon the eccentricity at which the journal is running in the bearing. It is impossible, of course, for pressure to exist in a practical bearing to a higher value than would be generated when side leakage is neglected, yet the equation offered will lead to such impossible pressures when used in an unthinking manner. It seems unfortunate that the author should propose such an inadequate equation and one so likely to lead the designing engineer astray.

With regard to the flow of oil through the film, if the film thickness at the entering end is twice that at the trailing end, it is evident that more than one-half of the entering oil must flow through the film in the direction of rotation of the journal surface. The remainder of the oil, less than 50 per cent of that which enters the film, must flow in part backward at the entrance and out at either side of the film. Therefore, even though the author may be able to figure a side area of outflow equal to ten times the area at the forward end of the bearing, in the case he assumes, more than one-half the oil would go in the direction of motion of the journal.

It is hoped that in the near future there will be sufficient information available, from experiments now being conducted to permit discussion of the problem of side leakage in journal bearings with the high degree of accuracy desirable for calculations.

AUTHOR'S CLOSURE

Such discussion of the paper as was critical or adverse was directed mainly to the formula attached to Fig. 2.

That was to be expected, since the formula is of an unconventional type, in so far at least as previous work on journal bearings is concerned, and is liable to misunderstanding unless its exact purport, as a solution of one case of the three-dimensional-lubrication problem, is carefully examined.

Probably the nature of the solution contained in the formula will be most readily understood from its analogy with more familiar theories and results; for example, the author's approximate solution of the thrust bearing of unlimited length in the direction of motion; or the accepted and universally used approximate theory of elastic beams.

The New Science[1]

WE HAVE developed the science of the infinitesimal, of the infinite, and of nearly every phenomenon in the earth beneath, the waters thereof and the heavens above so far as they relate to matter, force, and motion. The changes resulting from this new knowledge have transformed the environment of man, though they may have influenced his character but little. We find ourselves in the midst of an industrial civilization which has removed physical limitations and reduced manual burdens. This age of men and machines is hailed as a savior and condemned as a destroyer. Obviously, the machine itself is guiltless. If it serves, then the designer, inventor, and manager are to be commended. If the machine is a curse, then it seems that the person or persons responsible for the abuse are guilty. The machine can do no wrong: can break no laws. Laws may abolish certain tools or machines because they are to be used for evil purposes, just as men are removed from society because they are dangerous.

The science which has developed the materials and instruments of this age of power has been followed by applications which were impossible before. The art has followed the science rapidly. The skill of men has been equal to the materials and tools provided.

Science has developed a law of action for nearly every force known to man, but there has been no accepted science of manpower, no science to serve as a guide to the management of men. Numerous principles have been proposed commencing with the biblical injunction to do unto your neighbor as you would that he should do unto you. The psychologist has studied intelligence, nerve action, inhibitions, and complexes. The economist has studied trade, wealth, and cycles of various kinds. The social scientist has dealt with masses, movements, and legal restraints. None of these has attempted to develop either a theory or a practice of industrial operations, i.e., a science of management.

The earliest important contribution to a science of directing and using human energy was by Frederick Taylor, who applied the scientific method of measurement to tasks and approached the problem of wages and incentives in the same manner. Gantt, Barth, Emerson, the Gilbreths, and many others have contributed to this scientific achievement of the twentieth century. It has been summarized and formulated by Mr. L. P. Alford in a paper presented to The American Society of Mechanical Engineers in 1926, in which principles are laid down for handling materials, the product, and men.

In engineering education recently nothing has attracted more attention than instruction in the field of human relations and industrial proficiency. The personality of the student as well as scholarship is being considered, and the approach to industry is becoming rationalized. Sentimentalism is being replaced by facts and preparation. The induction process begins in college and continues well into industry. Systematic study is replacing a laissez faire attitude, and something of the scientific approach is being made. Enlightened management is no less an art but more of a science, and so far as it is a science we may not ignore it entirely in our engineering instruction. The methods employed may differ widely, but the purpose is to make the young man more familiar with some of the elementary principles.

[7] M.E., Kingsbury Machine Works, Philadelphia, Pa. Jun. A.S.M.E.

[1] Concluding portion of address delivered December 30, 1929, as Vice-President of Section M, American Association for the Advancement of Science, by R. L. Sackett (Mem. A.S.M.E.), Dean of Engineering, The Pennsylvania State College, at the annual meeting of the Association, Des Moines, Iowa.

Progress in Steam Research

Reports of Committees, of the International Conference at London, and of Work Carried Out at the Bureau of Standards and in Czechoslovakia

THE eighth annual session on Progress in Steam Tables Research was held on the afternoon of Wednesday, December 4, during the 1929 Annual Meeting of the A.S.M.E. Dean Arthur M. Greene, Jr., presided. A large audience of engineers, drawn to this meeting by the reputation which it has gained in years past as a forum for the discussion of the latest results of laboratory experimentation and theories and problems relating to the thermodynamics of vapors, listened with keen interest to the reports and papers which were presented. The contributions to this year's session will be found in the following pages.

Two important events which have taken place since last year's meeting deserve to be mentioned in connection with the reports and papers. As noted in the October issue of MECHANICAL ENGINEERING, a highly successful international conference on the steam table was called together in London on July 8, 1928. Representatives from England, Germany, and Czechoslovakia met with five representatives from this country for a five-day conference. As a result of the conference a "skeleton" table was agreed upon, which will be found in the official report of the conference published elsewhere in this issue. This establishes a network of fixed or test points in the saturated and superheated regions. At each of these points there is not only an agreed-upon value of volume and total heat, but also an agreed-upon tolerance or measure of uncertainty in each of these values. It was further agreed that if at each of these test points any present table lies closer than the selected tolerance to the selected value, then that table is, for the present at least, an international table. It is expected that the international fixed tabulation will be periodically and frequently revised, the first occasion for such a revision to be at a proposed meeting in 1930 at the World Power Conference in Berlin. Dr. Harvey N. Davis gave an interesting description of the London conference and summarized the official report which had just been received.

The other important development during the year was one affecting committee organization and was announced in the May issue of MECHANICAL ENGINEERING.

The A.S.M.E. Special Research Committee on the Thermal Properties of Steam has from its beginning in 1921 been adequately financed by the interested branches of the power industry. The manufacturers of equipment have joined with the principal groups of light and power companies in contributing the $85,000 necessary to cover the expenses of this investigation for the eight years from December, 1921, to December, 1929.

During this period Geo. A. Orrok served as chairman of the Executive Committee which received and administered this fund. In April, 1929, the Special Research Committee was reorganized and Alex Dow became its chairman. Mr. Dow is serving also as chairman of the Sub-Committee on Finance, and he is now soliciting contributions to cover the Committee's needs for the next five years. These needs are estimated at $20,000 each year, and it is confidently expected that the study will be completed at the end of that time.

The program for the session also contained two papers which will be found elsewhere in this issue. Prof. R. C. H. Heck, of Rutgers College, presented a paper entitled, "Notes on Formulation," and E. F. Mueller, of the Bureau of Standards, commented on the "Passing of the Mechanical Equivalent of Heat." There was much discussion of the reports and papers. Since the meeting, Prof. J. H. Keenan, of Stevens Institute of Technology, has made a comparative study of the new data, and the results have been included with the reports presented at the meeting.

It will be recalled that a year ago Professor Keenan offered to the A.S.M.E. a paper with which there was published a revised Mollier steam chart designed to include the critical-pressure region. This chart was based on the new data which the American investigators had made available, and was instantly in demand by all designers of steam machinery and students of the thermodynamics of vapors. Since the publication of this chart Professor Keenan has completed the compilation of a set of tables of the properties of saturated and superheated steam. These tables are, at the present writing, in process of being printed, and it is expected that they will be published and offered for sale at an early date.

These tables represent the first attempt in this country since the formation of the A.S.M.E. research committee on the thermal properties of steam to place before engineers complete tables covering the range of pressures and temperatures that are now being used and based largely on experimental data rather than extrapolated values. While they are not to be looked upon as tables of ultimately correct values such as it is hoped will be arrived at by further experimentation and the cooperation and agreement of international authorities, they do represent the best, in America at least, that our knowledge permits at present.

Report of the Technical Sub-Committee

GEO. A. ORROK, consulting engineer, chairman of the Technical Sub-Committee of the Special Research Committee on the Thermal Properties of Steam, reported as follows:

The work of the steam-table fund has been carried on through the year by a new committee organized under the chairmanship of Mr. Alex Dow, of Detroit, the Technical Sub-Committee being under the chairmanship of Mr. Orrok, Mr. Dow himself taking charge of the financial matters.

The experimental work has been carried along at the Massachusetts Institute of Technology and the Bureau of Standards. In Cambridge, work has been done in connection with the use of much larger bombs allowing larger samples or lower pressure, and about fifty new points have been secured. These matters are reported by Drs. Keyes and Smith. At the Bureau of Standards, quite a number of new values have been obtained for the specific heat of liquid water, as well as some further values for checking with the latent heats determined by the German investigators.

The Committee has been considering the work of the future and has laid out two programs, one of which may be completed in two years and the other in five years. It is hoped that money will be available to carry on the five-year program.

Through the generosity of Mr. Dow, money was available so that the investigators could accept the invitation of the English investigators to take part in a conference leading toward a tentative international steam table. This conference took place in London in July last. The tentative table which was adopted will be found in the report of the conference.

International Steam-Table Conference—Skeleton Steam Tables

DURING the week commencing Monday, July 8, 1929, there was held in London a conference of various physicists and engineers who are engaged in the experimental determination of the properties of steam or in the organization of the work. At this conference, which was convened by the British Electrical and Allied Industries Research Association, there were present the following, all of whom are interested in one or other phase of the investigation of the properties of steam:

America

DR. HARVEY N. DAVIS, President of Stevens Institute of Technology, Hoboken, N. J.
DR. H. C. DICKINSON, Bureau of Standards, Washington, D. C.
PROF. J. H. KEENAN, Stevens Institute, Hoboken, N. J.
GEORGE A. ORROK, Consulting Engineer, New York.
NATHAN S. OSBORNE, Bureau of Standards, Washington, D. C.

Great Britain

PROF. H. L. CALLENDAR, F.R.S., Imperial College of Science and Technology, South Kensington, London.
G. S. CALLENDAR, Imperial College of Science and Technology, South Kensington, London.
PROF. W. A. DALBY, F.R.S., City and Guilds (Engineering) College, London.
H. L. GUY, Metropolitan-Vickers Electrical Co., Ltd., Manchester.
I. V. ROBINSON, British Electrical and Allied Manufacturers' Association, London.
F. SAMUELSON, British Thomson-Houston Co., Ltd., Rugby.
DR. G. G. STONEY, F.R.S., C. A. Parsons & Co., Ltd., Newcastle.

Germany

DR. H. HAUSEN, Gesellschaft für Lindes Eismaschinen A. G., Munich.
PROF. DR. M. JAKOB, Physikalisch-Technische Reichsanstalt, Berlin.
GEHEIMRAT PROF. DR. O. KNOBLAUCH, Technical High School, Munich.
DR. W. KOCH, Technical High School, Munich.
GEHEIMRAT PROF. DR. R. MOLLIER, Technical High School, Dresden.

Czechoslovakia

DR. J. HAVLIČEK, Witkovitz Iron and Steel Works.
PROF. MISKOVSKY, The University, Prague.

Invitations were also sent to Professor Stodola, of Zurich, who was prevented by ill-health from attending, and to Prof. F. G. Keyes, of the Massachusetts Institute of Technology, Boston, Mass., who was unable to spare the necessary time.

The Conference was opened at 10:30 a.m. on Monday, July 8, by Dr. Daniel Adamson, president of the Institution of Mechanical Engineers, and was continued under the chairmanship of Sir Richard Glazebrook, F.R.S.

At the start of the Conference a general description of the apparatus that they had used was given by the different investigators, and certain information was exchanged regarding the methods adopted for correcting or limiting various errors.

A discussion then took place as to the form in which the final recommendation of the Conference should be presented. All delegates agreed that the best solution would be to draw up, in skeleton form, a small table of the properties of steam. To determine each figure to be inserted in the table, suggestions would be made by each of the four countries represented and a mean figure would be adopted together with a tolerance of an agreed magnitude. It was recognized that in some parts of the table the necessary tolerance might be relatively large, due probably to the different types of apparatus used by the various investigators giving results departing systematically from the results of other investigators.

A small committee was therefore appointed to consider this proposal in detail and prepare the desired skeleton tables. This committee consisted of the following:

America

DR. HARVEY N. DAVIS with the assistance of PROF. J. H. KEENAN.

Great Britain

G. S. CALLENDAR.

Czechoslovakia

PROF. MISKOVSKY

Germany

DR. M. JAKOB for saturated steam and DR. H. HAUSEN for superheated steam.

I. V. Robinson of the British delegation was appointed chairman of this committee.

SCOPE OF SKELETON TABLES

It was decided by the Committee, as regards the saturated-steam table, to take eight temperatures varying by steps of 50 deg. cent. from 0 deg. cent. to 350 deg. cent. and to determine for each temperature the following properties:

Saturation pressure
Specific volume of the liquid
Specific volume of the vapor
Total heat of the liquid
Total heat of the vapor.

For the superheated-steam tables it was decided to take a number of pressures varying from 1 atmosphere up to 250 atmospheres and to tabulate, for temperatures varying by intervals of 50 deg. cent. or 100 deg. cent., the specific volume and total heat of the steam.

UNITS AND CONVERSION FACTORS

In these skeleton tables the following units are used:

	Unit	Symbol
Length	Meters	m.
Specific volume	Cubic meters per kilogram	cu. m. per kg.
Pressure	Kilograms per square centimeter	kg. per sq. cm.
Temperature	Degrees centigrade	deg. cent.
Total heat	International kilo-calories, which by definition equals 1 kw-hr./860	kg-cal. per kg.

In any international comparison of physical data, an element of doubt is introduced by the small differences in the basic units employed in each country, and it was appreciated by the Committee that the units to be employed would have to be considered carefully and stated clearly. Their recommendations are herein detailed and their *raison d'etre* briefly explained.

Pressure Conversion Factor. In obtaining the conversion factor for pressure per unit area from the metric to the f.p.s. system and vice versa, the following have been assumed as basic figures.

1 pound = 453.5924 grams
1 inch = 2.54000 centimeters

With these values,

1 kg. per sq. cm. = 14.223334 lb. per sq. in.

In connection with this point it should be noted that the metric

equivalent of the inch employed is intermediate to the British and American legal values. These values are:

American: 1 inch = 2.540005 centimeters
British: 1 inch = 2.539996 centimeters

The American value is based upon the definition that the meter is $^{39.37}/_{12}$ of a foot, while the British value is the result of latest comparison of the standard meter and standard yard, this comparison having been made in 1922–1924. This slight difference has no appreciable effect upon the pressure conversion factor, as, if calculated upon the respective metric equivalents, this would be:

British: 14.223329 lb. per sq. in.
American: 14.223340 lb. per sq. in.

The adopted value 14.223 is therefore accurate to five significant figures on either the British or American basis, and has been used for the preparation of these tables.

In considering the relation between the pound and the gram, expressed above, the value of g does not enter into the calculation beyond insuring that the same value is used throughout. It is, however, desired to record that the standard value of 980.665 cm. per sec. per sec. has been used.

Specific-Volume Conversion Factor. Based upon the equivalents previously quoted for the inch and the pound, the factor, to obtain cubic meters per kilogram from cubic feet per pound, is:

$$\frac{(12 \times 2.54)^3}{0.453592 \times 10^6}$$

This is equal to 0.0624279, and the value of 0.06243 has been used

PROPERTIES OF SATURATED STEAM—ASSUMED MEAN VALUES AND TOLERANCES

	Temperature, deg. cent. 0°	50°	100°	150°	200°	250°	300°	350°
Saturation Pressure, Kg. per Sq. Cm.								
Mean value	0.00623	0.1258	1.0333	4.854	15.85	40.60	87.7	168.7
Tolerance ±	0.00001	0.0001	0.0000	0.002	0.01	0.05	0.1	0.1
Specific Volume of Liquid, Cu. M. per Kg.								
Mean value	0.00100	0.00101	0.00104	0.00109	0.00116	0.00126	0.00142	0.00179
Tolerance ±	0.00000	0.00000	0.00000	0.00000	0.00000	0.00001	0.00001	0.00003
Specific Volume of Vapor, Cu. M. per Kg.								
Mean value	206.4	12.06	1.674	0.393	0.1270	0.0501	0.0218	0.0089
Tolerance ±	0.1	0.01	0.001	0.001	0.0006	0.0002	0.0005	0.0002
Total Heat of Liquid, Int. Kg-Cal. per Kg.								
Mean value	0	49.95	100.04	150.93	203.6	259.5	321.8	403.7
Tolerance ±	0	0.02	0.02	0.03	0.04	0.3	1.0	2.0
Total Heat of Vapor, Int. Kg-Cal. per Kg.								
Mean value	595.4	618.5	639.2	656.0	667.5	670	657.5	617
Tolerance ±	1.2	1.0	0.5	1.5	2.0	3	5	7

PROPERTIES OF SUPERHEATED STEAM—ASSUMED MEAN VALUES AND TOLERANCES

Specific Volume of Vapor, Cu. M. per Kg.

	Pressure (Kg. per Sq. Cm.) and Temperature: 1 kg. 100° C.	1 kg. 200° C.	1 kg. 300° C.	1 kg. 400° C.	1 kg. 450° C.	1 kg. 500° C.	1 kg. 550° C.	5 kg. 200° C.	5 kg. 300° C.	5 kg. 400° C.	5 kg. 450° C.	5 kg. 500° C.	5 kg. 550° C.
Mean value	1.730	2.213	2.689	3.160	3.396	3.632	3.868	0.4331	0.5326	0.6294	0.6783	0.7242	0.7720
Tolerance ±	0.003	0.004	0.005	0.005	0.005	0.005	0.005	0.0006	0.0006	0.0006	0.002	0.002	0.002

	Pressure (Kg. per Sq. Cm.) and Temperature: 10 kg. 200° C.	10 kg. 300° C.	10 kg. 400° C.	10 kg. 450° C.	10 kg. 500° C.	10 kg. 550° C.	25 kg. 300° C.	25 kg. 400° C.	25 kg. 450° C.	25 kg. 500° C.	25 kg. 550° C.		
Mean value	0.210	0.2631	0.3125	0.3367	0.3604	0.3846	0.1011	0.1224	0.1327	0.1426	0.1523	.....	.....
Tolerance ±	0.0002	0.0003	0.0003	0.0003	0.0004	0.0004	0.0003	0.0003	0.0003	0.0003	0.0004	.....	.....

	Pressure (Kg. per Sq. Cm.) and Temperature: 50 kg. 300° C.	50 kg. 400° C.	50 kg. 450° C.	50 kg. 500° C.	50 kg. 550° C.	100 kg. 400° C.	100 kg. 450° C.	100 kg. 500° C.	100 kg. 550° C.	150 kg. 400° C.	150 kg. 450° C.	150 kg. 500° C.	150 kg. 550° C.
Mean value	0.0465	0.0591	0.0645	0.0698	0.0749	0.0271	0.0305	0.0334	0.0361	0.0162	0.0190	0.0212	0.0232
Tolerance ±	0.0004	0.0004	0.0004	0.0004	0.0005	0.0004	0.0004	0.0004	0.0005	0.0003	0.0003	0.0004	0.0005

	Pressure (Kg. per Sq. Cm.) and Temperature: 200 kg. 400° C.	200 kg. 450° C.	200 kg. 500° C.	200 kg. 550° C.	250 kg. 400° C.	250 kg. 450° C.	250 kg. 500° C.	250 kg. 550° C.					
Mean value	0.01028	0.01312	0.01512	0.01673	0.00636	0.00940	0.01136	0.0130	.....	.....	.....	.....	.....
Tolerance ±	0.00005	0.00025	0.00035	0.00045	0.00005	0.00015	0.00030	0.0004	.....	.....	.....	.....	.....

Total Heat of Vapor, Int. Kg-Cal. per Kg.

	Pressure (Kg. per Sq. Cm.) and Temperature: 1 kg. 100° C.	1 kg. 200° C.	1 kg. 300° C.	1 kg. 400° C.	1 kg. 450° C.	1 kg. 500° C.	1 kg. 550° C.	5 kg. 200° C.	5 kg. 300° C.	5 kg. 400° C.	5 kg. 450° C.	5 kg. 500° C.	5 kg. 550° C.
Mean value	639.4	687.5	735.3	783.4	807.7	832.6	858.0	682.5	732.5	781.7	807.0	831.6	857.5
Tolerance ±	0.1	1.0	1.5	1.5	1.5	1.5	2.0	1.5	2.0	2.0	2.0	2.0	2.0

	Pressure (Kg. per Sq. Cm.) and Temperature: 10 kg. 200° C.	10 kg. 300° C.	10 kg. 400° C.	10 kg. 450° C.	10 kg. 500° C.	10 kg. 550° C.	25 kg. 300° C.	25 kg. 400° C.	25 kg. 450° C.	25 kg. 500° C.	25 kg. 550° C.		
Mean value	676.2	729.5	780.0	805.0	830.2	856.5	719.8	774.4	800.5	827.7	853.8	....	....
Tolerance ±	1.5	2.0	2.0	2.0	2.0	2.0	1.5	1.5	1.5	2.0	2.5	....	....

	Pressure (Kg. per Sq. Cm.) and Temperature: 50 kg. 300° C.	50 kg. 400° C.	50 kg. 450° C.	50 kg. 500° C.	50 kg. 550° C.	100 kg. 400° C.	100 kg. 450° C.	100 kg. 500° C.	100 kg. 550° C.	150 kg. 400° C.	150 kg. 450° C.	150 kg. 500° C.	150 kg. 550° C.
Mean value	700.6	764.0	793.5	822.0	850.0	741.7	776.3	809.5	840.0	713.9	757.7	797.5	832.0
Tolerance ±	2.5	2.6	2.0	3.0	5.0	3.0	3.0	3.0	5.0	3.0	3.0	4.0	5.0

	Pressure (Kg. per Sq. Cm.) and Temperature: 200 kg. 400° C.	200 kg. 450° C.	200 kg. 500° C.	200 kg. 550° C.	250 kg. 400° C.	250 kg. 450° C.	250 kg. 500° C.	250 kg. 550° C.					
Mean value	676.0	736.0	784.0	823.0	622.0	712.0	769.0	812.0	....	....	...	....	....
Tolerance ±	2.5	4.0	6.0	8.0	4.0	6.0	8.0	10.0	....	....	...	....	....

as being sufficiently accurate. So that we have: 1 cubic foot per pound = 0.06243 cubic meter per kilogram, or reciprocally, 1 cubic meter per kilogram = 16.0184 cubic feet per pound.

Heat Units. Before the appointment of the Committee, the Conference considered carefully the units in which the total heat was to be recorded. It was felt to be very desirable that the adopted unit should be one which would avoid any complication due to the variation in the acceleration of gravity in various parts of the world or the variation of the specific heat of water with temperature, and also that it was desirable to avoid a definition which involved a change in the value of Joule's equivalent with each improvement in calorimetric technique. It was pointed out that electrical units were independent of both g and J, that they were known accurately within very narrow limits and were internationally accepted, and that, therefore, it would be very desirable to secure the general acceptance of a calorie defined in terms of the watt-hour.

This unit, the kilo-calorie, should actually not differ very greatly from the heat units used up to the present time, and should be obtained from an electrical unit by means of a conversion factor which is easily remembered.

A unit defined by the heat equivalent of an international kilowatt-hour divided by 860 meets these claims, and it was accepted by the Conference as a basic unit for these tables and it is recommended that it should be designated as the "international kilo-calorie."

The international kilo-calorie differs from the kilo-calorie used up to now in various countries by less than plus or minus 0.05 per cent, which is an insignificant amount. It has, however, the great advantage of being independent of the determinations of the electrical heat equivalent, which differ slightly from one another.

In his work Professor Callendar has used the mean calorie with a value of 4.185 joules. The German investigators have used the 15-deg. cent. calorie with a value of 4.184 joules, while the American investigators have used the new Bureau of Standards value for the mean calorie, viz., 4.1876 joules, whereas the unit as defined above has a value of 4.186 joules.

International Temperature Scale. The Conference adopted the international temperature scale which, as is well known, is determined by the temperature of the ice point, the temperature of ebullition of water under a normal metric atmosphere, and the boiling point of sulphur, 444.60 deg. cent., also under a normal metric atmosphere.

Definitions: (a) Saturated Pressure at 100 Deg. Cent. On the constant-volume hydrogen thermometer scale, a temperature of 100 deg. cent. is defined as the temperature of the vapor of distilled water in ebullition under a pressure equal to a normal metric (physical) atmosphere. This, in turn, is defined as the pressure corresponding to a column of mercury 76 cm. in height under standard gravity conditions, i.e., g = 980.665 cm. per sec. per sec. and at 0 deg. cent. The density of mercury at 0 deg. cent. being 13.5955 grams per cu. cm., the normal physical atmosphere pressure is 1033.258 or, say, 1033.3 grams per sq. cm. Thus the saturation pressure at 100 deg. cent. is defined as being 1.0333 kg. per sq. cm. under standard gravity conditions. This is therefore not an agreed value but a definition, and as such needs no tolerance.

(b) Heat of Liquid at 0 Deg. Cent. The one other definition that has to be mentioned is the total heat of the liquid at 0 deg. cent. It has always been the custom of all investigators and authors of steam tables to define the total heat of a liquid or vapor as the heat content in excess of that contained by the liquid at 0 deg. cent. and saturation pressure. This latter content is therefore zero by definition.

Compilation of Skeleton Tables

Dealing now with the actual determination of the figures to be inserted in the skeleton tables, each delegation calculated from the determinations of its own members some or all of the figures required for the tables, and these were then compared carefully. In deciding upon the figures to be inserted in the skeleton tables, based upon the various national proposals, due consideration was given to the method in which the figures had been determined. More weight was attached to the figures which were the result of direct experiment than to those which were merely an extrapolation from other work.

The figures thus inserted in the tables did not represent a mechanical averaging of the national figures, but were the result of a very careful consideration of the relative values of the different proposals. In this way the figures given in the tables and the tolerances attached to each figure were obtained. These values were unanimously accepted by the Conference as representing the first stage in their deliberations.

Since the conclusion of the Conference each delegate has verified or corrected the figures submitted in the Committee, and the skeleton steam tables attached hereto are based upon the confirmed figures.

Further Investigations

Those figures for which it has been found necessary to allow a comparatively large tolerance were recognized as presenting special difficulties and requiring further detailed experimental investigations. It is hoped that as a result of this further investigation the figures might be varied at a later conference, so that the range of national values for any one figure may be reduced and consequently the tolerances also reduced. In addition, at such further conference, values for a larger number of pressures and temperatures may be inserted.

With this step-by-step method of improving the skeleton table and reducing the tolerances, it is hoped that it may be possible in a comparatively short time to get a skeleton table which is accurate within very small margins and accepted by all recognized authorities.

The Committee and the Conference were quite clear that on account of the method employed in setting up the skeleton tables the values adopted for the total heat and for the specific volume might not be thermodynamically consistent in the strict scientific sense, since according to theory all other values can be derived from only two quantities of state (for instance, temperature and pressure), if a perfectly correct equation of state is available. It is also possible that for given values of the pressure and temperature, the values of the specific volume and total heat in the tables might contradict each other. By the choice of large tolerances, however, such a contradiction should be practically excluded.

Should, in the meantime, any nation represented at the conference, or, it is hoped, others not so represented, desire to produce further steam tables, these should be so calculated that they give values for any property in the steam table coming within the range of tolerances given for that property in the skeleton tables, as there would be considerable doubt as to the accuracy of any figures falling outside this range of tolerances.

It has been felt desirable that some explanation should be given of the methods which were used in arriving at the figures given in the skeleton tables, as the idea of a tolerance in regard to the properties of steam is novel but is well suited to the present circumstances.

Once more it is desired to call attention to the fact that the Conference has been confined to those physicists and engineers actually connected with the research work into the properties of steam, and invitations were not extended to others who, although closely interested in the use of steam tables, are not actually carrying out such research work.

Report on Progress in Steam Research at the Massachusetts Institute of Technology[1]

By L. B. SMITH[2] and F. G. KEYES,[3] CAMBRIDGE, MASS.

IN HIS annual report of a year ago, Professor Keyes told you that we were prepared to measure the coefficients of expansion of the various metals used in the construction of the steam containers. Samples were cut from the pieces of metal actually used in making the steam bombs, and with the valuable aid of Mr. Jacobus, a member of the laboratory staff, their linear expansion was accurately measured over a wide temperature range. The Pulfrich interferometer obtained from Carl Zeiss was used for this work.

With these expansion data we were now in a position to calculate the volumes of the spherical steel bombs, and could go ahead with our superheat measurements at the larger specific volumes.

First, a loading of water was made for 20 cc. per gram. This was designed as a check on the measurements previously made in the nickel bomb.

Of course we realized that were equilibrium between iron and steam to be reached, a considerable pressure of hydrogen would

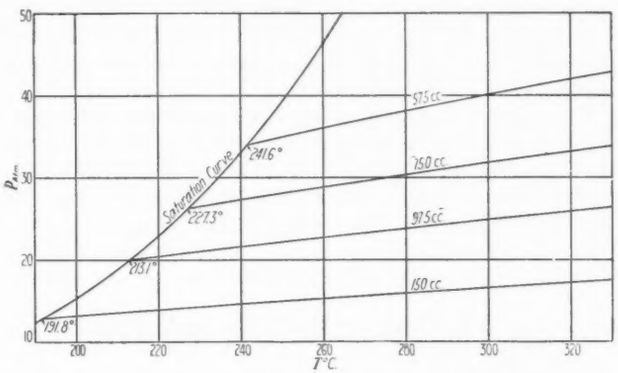


FIG. 1 ISOMETRICS FOR FOUR LOADINGS PLOTTED ON A *p-t* DIAGRAM, TOGETHER WITH A SECTION OF THE VAPOR-PRESSURE CURVE

be generated. The perfect lack of action of air-free water on a brightly polished steel surface at ordinary temperatures led us to hope that the action at higher temperatures would not be troublesome. In this, however, we were doomed to disappointment, as was soon made evident to us.

As soon as the temperature was raised and measurements started, the presence of fixed gas was detected. In fact, we were able to follow the gas evolution and observe that the quantity present reached a maximum and constant amount. The partial pressure of hydrogen in the bomb finally attained a value of about 0.2 atmosphere. It will be recalled that when we were working with the nickel bomb an initial oxidation of the nickel with evolution of hydrogen was followed soon after by disappearance of the hydrogen. This could be accounted for by the known permeability of nickel to hydrogen. The fact that in the steel bomb the hydrogen reached a constant pressure which was very much lower than that to be expected from equilibrium calculations,[4] led us to conclude that a protective film of oxide was formed which would prevent further action.

A second loading, this time for 30 cc. per gram, was accordingly made, but premature rupture of the gold locking disk rendered this loading worthless.

The next loading was for 40 cc. per gram. Measurements of vapor pressure revealed discrepancies even greater than those observed in the first case, and much time was consumed in checking all possible sources of error before the real explanation was hit upon. Finally the steam loading was blown off into an evacuated vessel to which a manometer was attached. The water was condensed with liquid air and the residual-gas pressure measured. The quantity of residual gas was found to account entirely for the discrepancy in the vapor-pressure measurements.

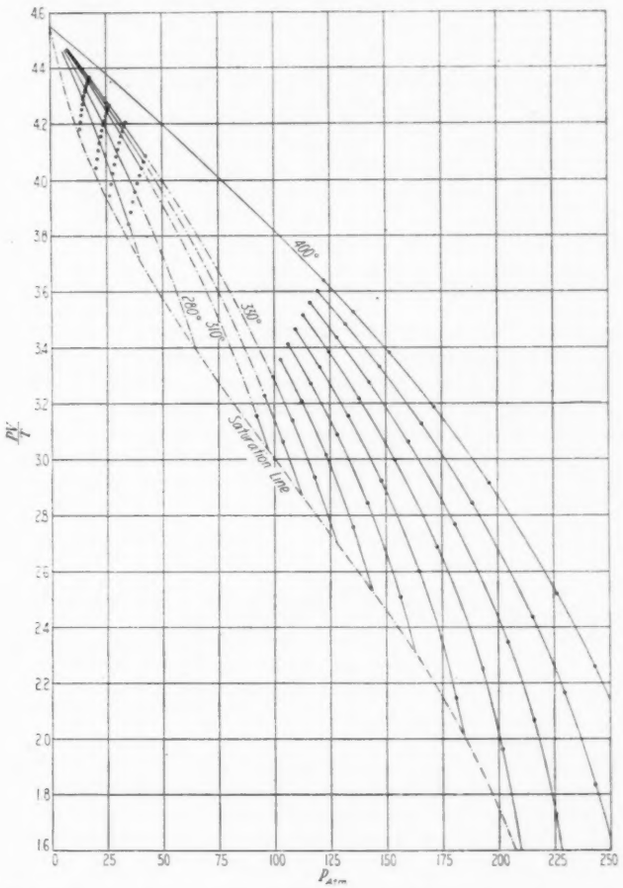


FIG. 2 COMPARISON OF NEW DATA WITH PREVIOUSLY REPORTED HIGH-PRESSURE DATA

We therefore concluded that in heating and evacuating the bomb in preparation for the third water loading, the iron oxide film had dissociated, the oxygen being pumped off and a very active surface of reduced iron being left. In making subsequent loadings great care was taken not to heat the bomb enough during evacuation to cause dissociation of the protective oxide film. When this precaution was observed, no further trouble with hydrogen evolution was experienced.

[1] Research Laboratory of Physical Chemistry, Massachusetts Institute of Technology. Publication No. 233.

[2] Assistant Professor of Physico-Chemical Research, Massachusetts Institute of Technology.

[3] Director of Research Laboratory of Physical Chemistry, Massachusetts Institute of Technology.

[4] Eastman, *Jl. Am. Chem. Soc.*, vol. 44 (1922), p. 975. Eastman and Evans, ibid., vol. 46 (1924), p. 888.

Four additional loadings have been made covering the range of specific volumes from 57.5 cc. per gram to 150.0 cc. per gram. (See Table 1.) Fig. 1 shows these isometrics plotted on a *p-t* diagram, together with a section of the vapor-pressure curve. Saturation specific volumes of the vapor corresponding to the isometrics have been obtained by extrapolation of the constant-volume lines to intersection with the vapor-pressure curve.

In order to gain some idea of the consistency of these new data with those previously obtained, Fig. 2 has been prepared. Here pv/T is plotted against p. The points grouped at the upper left represent the new data, while those at the right are the previously reported high-pressure data. The lower broken line is the saturation curve; all others are lines of constant temperature. It will be seen that the group of points representing the 75.0-cc. per gram isometric is not altogether consistent with the rest of the points. An error in the loading or in calculating the settings would easily account for this discrepancy. Of course, at the first opportunity this will all be checked, and ultimately check measurements will be made with entirely new loadings. New samples of water have been prepared for this purpose and for making measurements at specific volumes between 20 and 57.5 cc. per gram.

TABLE 1 ADDITIONAL MEASUREMENTS OF SUPERHEATED STEAM

Temp., deg. cent.	Specific volume, cu. cm. per gram — Pressure in Atmospheres 57.500	75.000	97.500	150.000
200	....	....	....	13.196
210	....	....	....	13.560
220	....	....	20.458	13.918
230	....	26.476	21.046	14.269
240	....	27.290	21.621	14.614
250	34.966	28.081	22.185	14.955
260	36.034	28.850	22.738	15.291
270	37.072	29.597	23.279	15.624
280	38.086	30.331	23.814	15.954
290	39.082	31.055	24.340	16.282
300	40.058	31.768	24.862	16.606
310	41.015	32.470	25.376	16.926
320	41.959	33.161	25.882	17.245
330	42.894	33.842	26.384	17.564
No. of points.....	16	18	26	23
Average deviation, per cent.....	0.080	0.033	0.082	0.057

Total number of points = 83
Total average deviation = 0.064 per cent.

Making use of the Clapeyron equation, four values of the latent heat of evaporation of water have been calculated corresponding to the four new vapor-saturation specific volumes. These are given in Table 2 with corresponding values by Jacob and Fritz and by Knoblauch.

TABLE 2 VALUES OF LATENT HEAT OF EVAPORATION OF WATER

Temp., deg. cent.	Heat of evaporation (cal. per gram) — M.I.T. (calc.)	Knoblauch (calc.)	Jacob and Fritz (obs.)
191.8	468.4	469.6	470.1
213.1	449.1	448.5	450.2
227.3	433.9	433.5	435.6
241.6	416.7	417.6	419.8

At the time it became necessary to temporarily suspend experimental work in order to prepare for this conference, an investigation of that portion of the superheat field lying close to saturation was in progress. This was undertaken to settle the question as to what justification we have for extrapolating the isometrics to intersection with the saturation curve. It appears that as the saturation line is closely approached there is a slightly increased tendency for collapse of the vapor phase. It is too early to make definite statements as yet, but the indications are that this effect will be quite small in magnitude and either entirely negligible or readily allowed for.

In conclusion, it may be stated that on account of the lack of consistency in our new determinations and the fact that we have not as yet had opportunity to make direct check measurements, we must request that for the present they be given only preliminary weight.

Vapor Pressure of Water From the Ice Point to the Critical Temperature[1]

BY F. G. KEYES[2] AND L. B. SMITH,[3] CAMBRIDGE, MASS.

PROFESSOR SMITH has reported further data on the measurements which have been taken on the volumes of superheated steam since the meeting of a year ago. It will be recalled that it was considered necessary for the measurement of specific volumes in excess of 20 cc. per gram (0.32 cu. ft. per lb.) to change the nickel steam container for one of larger capacity. The new containers are of steel and have proved to be satisfactory after suitable "steam treatment," which process is completely described by Professor Smith in the course of his report.

A few additional measurements of the vapor pressure of water have been obtained during the course of the superheat measurements, but these newer measurements were not used in the correlation of all the available data, the presentation of which is the object of the present paper. The measurements taken during the year agree satisfactorily with the "mean values" deduced from the correlation procedure, as will be perceived in detail below.

[1] Research Laboratory of Physical Chemistry, Massachusetts Institute of Technology. Publication No. 232.

[2] Director of the Research Laboratory of Physical Chemistry, Massachusetts Institute of Technology.

[3] Assistant Professor of Physico-Chemical Research, Massachusetts Institute of Technology.

METHOD OF CORRELATION

During the past twenty years, the writer has attempted to use many forms of vapor-pressure equations. None of the equations which have been proposed are quite satisfactory, and the more consistent the data to be correlated, the less satisfactorily do most of the usual equations represent the data over any extended range of temperature.

The number of forms which have been proposed to relate vapor pressures to the corresponding temperatures are very numerous; in fact, nearly as numerous as the number of equations of state which have been proposed. The "theory" which may be invoked to provide a basis for deducing a rational relation between pressure and temperature is preferably thermodynamical. The starting point may be the Clapeyron equation. Using the usual approximations involving the perfect-gas laws and series expressions for heat capacities, the following equation is obtained:

$$\log p = -\frac{A}{T} + B + C \log T + a_1 T + a_2 T^2 + \ldots + a_n T^n \ldots [1]$$

This equation is in some respects satisfactory, but where a long range of temperature is to be covered the difficulty of "adjusting"

the constants to fit the data is, to say the least, exceedingly time-consuming. The same remark applies to any of the variants of the above equation.

The procedure here adopted is that sketched in the writer's ammonia tables,[4] and depends on an equation given by van der Waals. This equation may be regarded merely as one of an innumerable set of equations representing that the pressure and temperature mark the end of the vapor-pressure curve. The equation is as follows, where the subscript c refers to the critical state.

$$\log \frac{p_c}{p} = a\left(\frac{T_c}{T} - 1\right) \ldots\ldots\ldots [2]$$

This equation has a "constant" a which has been known for a long time to be actually a function of the temperature. In using the equation to represent vapor-pressure data[5] it is preferable to transform it, using x to represent $(T_c - T)$. Equation [2] now becomes:

$$Z = \frac{\log p_c - \log p}{x} T = a = a_0 + a_1 x + a_2 x^2 + \ldots. [3]$$

The M.I.T. vapor-pressure data used represent a total of about 258 separate measurements taken between 150 deg. cent. and the critical temperature (374.11 deg. cent.). The total of these measurements and those of K. Scheel and W. Heuse[6] and of L. Holborn and F. Henning[7] as given in the "Wärmetabellen" of the Physikalisch-Technischen Reichsanstalt[8] for temperatures below 150 deg. cent. were used to compute values of a from Equation [3]. The relation of the a-values to temperature (x) involves a minimum and intercepts the Z-axis for $x \to 0$ with a value of $a = a_0 = 3.4763$; a value very roughly the same for all substances. The minimum may be readily eliminated by reducing the order of the a-equation, which is possible since a_0 has been determined by choosing the intersection of the a,x curve with the a-axis.

A new function may now be defined as follows:

$$Y = \frac{Z - a_0}{x} = a_1 + a_2 x + a_3 x^2 + \ldots\ldots\ldots [4]$$

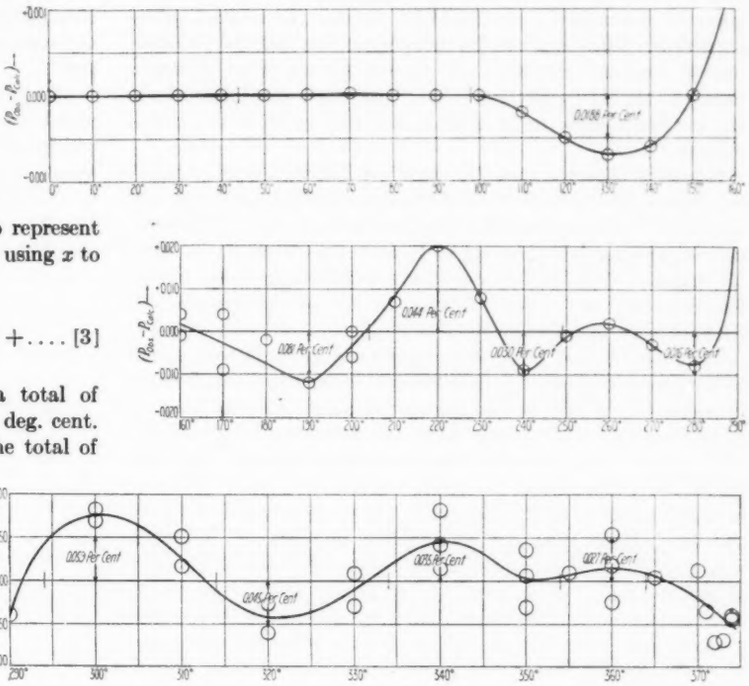


FIG. 2

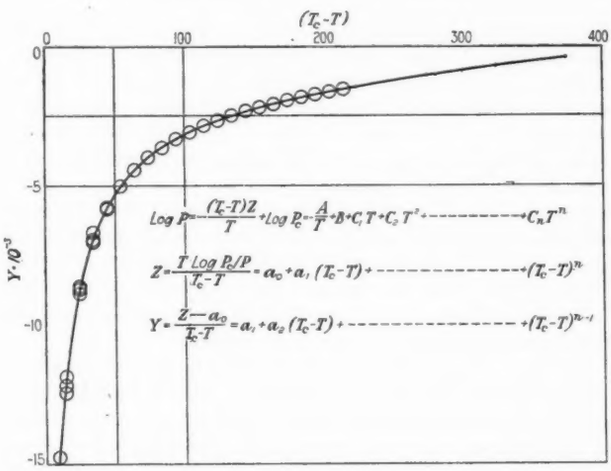


FIG. 1

A plot of Y versus x is given in Fig. 1, where the circles represent the average values of the pressure measurements taken at round temperatures. The upper part of the curve corresponds to the pressures from 0 deg. cent. to 150 deg. cent.

The attempt to represent the entire range of Y-values from 0 deg. cent. to 374.1 deg. cent. by a single equation proved to be impractical and the curve was divided into three sections for representation. The first section, I, embraces the data from 0 to 150 deg. the second section, II, from 150 to 290 deg., and the third section, III, from 290 to 374 deg. cent. The equations follow:

$$\log p = 2.3395111 - \frac{1}{T}\left[a_0 x + Y x^2\right] \ldots\ldots\ldots [5]$$

$t_c = 374.11 \qquad a_0 = 3.4763 \qquad T = 273.13 + t°\ \text{C.}$

I (0–150 deg. cent.):

$$10^3 Y = -4.494947 + 2.000419 \cdot 10^{-2}\, x - 3.593284 \cdot 10^{-5} x^2 + 3.143572 \cdot 10^{-8} x^3$$

II (150–290 deg. cent.):

$$10^3 Y = -7.371777 + 6.340868 \cdot 10^{-2}\, x - 2.572841 \cdot 10^{-4} x^2 + 4.115226 \cdot 10^{-7} x^3$$

III (290–374 deg. cent.):

$$10^3 Y = -21.944157 + 1.022158\, x - 2.808741 \cdot 10^{-2} x^2 + 4.225870 \cdot 10^{-4} x^3 - 3.224082 \cdot 10^{-6} x^4 + 9.724372 \cdot 10^{-9} x^5$$

---

[4] Keyes, "Thermodynamic Properties of Ammonia." John Wiley and Sons, 1926, p. 9.

[5] Attention should be called to the fact that Prof. Lionel S. Marks was, so far as the writer knows, the first to use Equation [2] as a basis for the exact correlation of vapor-pressure data. Professor Marks' paper appeared in the Jl. A.S.M.E., vol. 33 (1911), p. 563.

[6] *Ann. d. Phys.*, vol. 29 (1909), p. 723; vol. 31 (1910), p. 715.

[7] Ibid., vol. 26 (1908), p. 833; vol. 31 (1910), p. 945.

[8] The values as given in the tables were of course "corrected" to conform to the scale of the pure platinum resistance thermometer, where in addition to the freezing and normal boiling point of water, sulphur boiling at 444.6 deg. cent. under normal pressure is used to fix the constants of the thermometer. This scale has been agreed upon for use by the American steam investigators.

FINAL VAPOR-PRESSURE VALUES

The computed vapor pressures based on the above equations agree with the actual vapor pressures very satisfactorily. The first range gives a maximum deviation of 0.04 per cent; the second, of 0.097 per cent; and the third, of 0.097 per cent.

A deviation curve, Fig. 2, was constructed from the computed and observed data which enabled a final selection to be made of what are considered to be the best values of the vapor pressures of water as determined from the M.I.T. work. These final values are given in Table 1, where the first column contains the temperature in degrees centigrade, the second the computed pressures (using I, II, III in Equation [5]), the third the final values, and for comparison the Reichsanstalt values given in the fourth column.

It is to be observed that the "final" M.I.T. values are in excellent agreement with the data of the Reichsanstalt as far as 300 deg. cent. Above the latter temperature a steady difference makes appearance amounting to about 0.2 per cent at the critical region. The M.I.T. results are larger than those of the Reichsanstalt, and possible "explanations" of the pressure differences may be of interest.

The most obvious cause of a higher pressure could be assigned to the presence of air or permanent gas in the water under measurement. It would be impossible to state that no trace of permanent gas was present, were measurements ever so carefully made. The greatest danger from this cause of high values lies indirectly in the great chemical reactivity of water with the material of the container. With nickel, should chemical equilibrium ensue, a considerable quantity of hydrogen would be evolved from the formation of a very small quantity of nickel oxide. With iron, similar action would take place. The preliminary investigations made to determine the characteristics of the reactivity of water with the walls of our containers showed, however, that at 400 deg. cent. and below a slight film of oxide is formed which appears to completely inhibit further action of the water on the nickel or steel. This sort of inhibition is a common phenomenon in chemistry.

But direct tests were always made to determine whether permanent gas was present or not. From the earlier reports it will be recalled that the apparatus employed permitted the vapor phase to be collapsed or created at will. By this device vapor-pressure measurements could be made at successively smaller ratios of vapor to liquid up to the point of the disappearance of the vapor phase. It is self-evident that any permanent gas present would exert an accumulating pressure and thereby disclose itself. No measurements were accepted which showed the slightest increase in pressure on successive measurements down to the virtual collapse of the vapor phase. It is of course true that a portion of any permanent gas would dissolve in the liquid. The solubility would extend, however, only so far as proportionality to the partial pressure. We feel confident that the differences in pressure above 300 deg. cent. cannot be ascribed to the presence of permanent gas and must be sought elsewhere.

The question of the temperature scale may be considered in relation to the differences in pressure. Here we have some very definite data on which to base a statement. Previous reports have discussed the difficulty of reproducing the same temperature scale with different thermometers. The platinum resistance thermometer when constructed of the purest platinum according to certain specifications does possess a reproducibility probably greater than any other thermometric instrument, at least for the temperature range 0 deg. cent. to the sulphur boiling point 444.6 deg. cent. At the Research Laboratory of Physical Chemistry a larger number of platinum thermometers (16) constructed of successive portions of the same platinum wires have now been subjected to considerable observation. The conclusion from these observations seems to warrant the statement that the maximum reproducibility to be expected from platinum thermometers is about 0.01 deg. cent. at 300 deg. cent. The number may be as great as 0.02 deg. cent., but is certainly not less than 0.01 deg. cent. Perhaps this should be regarded as a sufficient achievement since 0.01 deg. cent. is one thirty-thousandth of 300. In any event, at 300 deg. cent. such a difference would account for about the difference between the M.I.T. and the Reichsanstalt measurements at 300 deg., but cannot account for the continually increasing differences in pressure above 300 deg. cent.

The only possibility which appears to remain is to investigate whether the different construction and manner of using the deadweight gage would be the cause of the pressure differences. The most conspicuous difference between the Budenberg gage used by the Reichsanstalt and the M.I.T. type of gage lies in the device by which equilibrium is detected. In the Budenberg gage the rise or fall of the piston is directly observed by means of

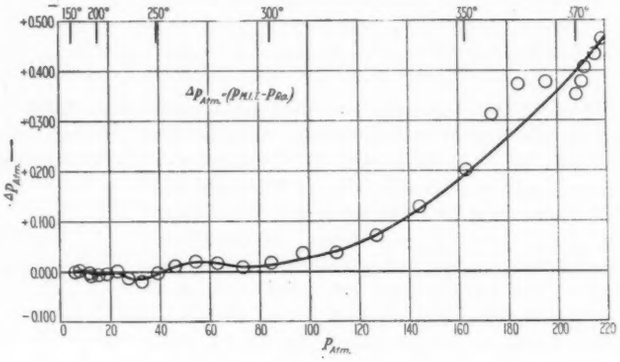


FIG. 3

a lever-multiplying index device. With the M.I.T. indicator a mercury U is employed between the gage and the pressure vessel. The mercury U container, of 1/8 in. bore, is provided with insulated needles which are used to detect a motion of the mercury meniscus. It has been established that an electrical contact between a point and a mercury surface will make or break for a displacement of 0.01 mm. (0.0004 in.). Accordingly with a 3/8-in. piston in the gage a vertical motion of about 0.001 mm. (or 0.00004 in.) of the pressure piston can be detected. Moreover a little reflection will show that the escape of the oil about the measuring piston has no effect on the pressure equilibrium in the above-described manner of detecting the equilibrium. With the Budenberg lever arrangement, however, the rate of escape of the oil can produce an error in the observed pressure and of a magnitude increasing with increasing pressure.

The type of gage employed in the M.I.T. measurements has been compared directly with a mercury column to 600 atmospheres. Hence the measurements of pressure are not dependent on any assumptions whatever regarding the functioning of the deadweight gage. The pressures are as though compared directly with the mercury column.

In the interest of clearing up the discrepancy in the pressure measurements above 300 deg. cent., it is hoped that a direct comparison of the actual gages used at M.I.T. and the Reichsanstalt may some time be affected. The plot, Fig. 3, gives a graphic representation of the deviations in the two sets of vapor-pressure data.

RECENT VAPOR-PRESSURE MEASUREMENTS

A few measurements of vapor pressures of steam have been made in the course of the measurements of the large superheat

TABLE 1 VAPOR PRESSURE OF WATER

Temp., deg. cent.	p computed	"Observed" p, final	Wärmetabellen value, corrected	Δp
160.00	6.098	6.100	6.100	0.000
170.00	7.822	7.819	7.817	+0.002
180.00	9.901	9.893	9.895	−0.002
190.00	12.388	12.378	12.386	−0.008
200.00	15.338	15.335	15.341	−0.006
210.00	18.811	18.818	18.823	−0.005
220.00	22.870	22.890	22.889	+0.001
230.00	27.582	27.590	27.603	−0.013
240.00	33.015	33.007	33.027	−0.020
250.00	39.232	39.231	39.234	−0.003
260.00	46.309	46.311	46.300	+0.011
270.00	54.314	54.311	54.291	+0.020
280.00	63.319	63.311	63.295	+0.016
290.00	73.468	73.428	73.42	+0.008
300.00	84.722	84.797	84.78	+0.017
310.00	97.409	97.436	97.40	+0.036
320.00	111.508	111.467	111.43	+0.037
330.00	127.071	127.061	126.99	+0.071
340.00	144.282	144.328	144.20	+0.128
350.00	163.356	163.361	163.16	+0.201
355.00	173.634	173.642	173.33	+0.312
360.00	184.428	184.443	184.07	+0.373
365.00	195.790	195.797	195.42	+0.377
370.00	207.861	207.842	207.49	+0.352
371.00	210.384	210.358	209.98	+0.378
372.00	212.951	212.917	212.51	+0.407
373.00	215.565	215.523	215.09	+0.433
374.00	218.233	218.183	217.72	+0.463

volumes. These data are collected in Table 2, where the second column gives the observed pressures in the steel container. The third column contains the "final" values appearing in Table 3 for comparison. The "final" values, it will be recalled, were measured with the steam contained in nickel. The differences in pressure given in the fourth column are about those to be expected and amount on an average to about one part in 3000 of the actual pressure.

TABLE 2 NEW VAPOR PRESSURES

t, deg. cent.	New in steel bomb, "Final values" $p_{obs.}$	p_{final}	$(p_{obs.} - p_{final})$
170	7.814	7.819	−0.002
	7.820		
180	9.896	9.893	+0.003
190	12.382	12.378	+0.008
	12.390		
200	15.345	15.335	+0.010
210	18.825	18.818	+0.007
220	22.887	22.890	−0.003
230	27.598	27.590	+0.011
	27.603		

THE VAPOR PRESSURES BELOW 160 DEG. CENT.

It is believed that the values of the vapor pressure already available for temperatures below 160 deg. cent. are entirely satisfactory. In the course of the correlation work this range of data has been carefully considered and the values are represented by I of Equation [5] to 150 deg. cent., with a maximum difference of 0.041 per cent at 10 deg. cent. The vapor-pressure-temperature relation for steam may be assumed to be known over its entire range from 0 to 374 deg. cent. within one part in 3000. The only possible doubt regarding the strict validity of this statement would appear to be in connection with the last 40 deg. of the temperature range, where differences between the "Reichsanstalt" values and the M.I.T. values increase to a maximum of 1 in 500 of the pressure at the critical temperature.

Report on Progress in Steam Research at the Bureau of Standards, With Determinations of Heat Content and Latent Heat Up to 270 Deg. Cent.[1]

BY N. S. OSBORNE,[2] H. F. STIMSON,[3] AND E. F. FIOCK[3] WASHINGTON, D. C.

THE work of the past year has consisted of additional experiments on the heat content of liquid water at temperatures from 100 deg. cent. to 270 deg. cent., and a series of measurements of the heat of vaporization at temperatures from 100 deg. cent. to 270 deg. cent.

The experiments on the liquid supplement those previously reported[4] and modify them only very slightly. A complete description of the apparatus, methods of measurement, and computation of results will be prepared for publication in the near future. The essential features have already been briefly described in previous reports. A résumé of the results of the experiments completed will be given.

It appeared that only slightly greater precision would result from continuation of the experiments on the liquid in the range from 0 deg. to 270 deg. Instead either of pursuing this course or of extending the range of these heat-capacity measurements from 270 deg. up to 300 deg., it was decided that the latent-heat determinations offered the best promise of yielding useful data.

During these latter experiments the underlying principles of the method and apparatus have proved sound. By various changes in auxiliary equipment and in manipulative technique, the range of satisfactory operation has been extended to 270 deg. cent.

The method of measurement consists in the observation of the electric energy required to evaporate and remove water as saturated vapor at a constant temperature from a charge in the calorimeter. The supply of energy is utilized in evaporating water from a thin film of liquid caused to pour over the electric heater by the centrifugal pump which circulates the water within the calorimeter. After leaving the calorimeter, the vapor passes through a delicate throttle valve located in the oil bath outside the calorimeter itself. One purpose of this is to drop the pressure to the receiver pressure. At the same time, fine operation of the throttle, hand controlled by the observer, serves to regulate the evaporation so that a steady state is shown by the observed temperature of the calorimeter. After passing the throttle, the vapor enters a manifold with three shut-off valves, each of which admits the flow to a line connected with a receiver for the fluid withdrawn. These valves are electrically operated by the signal from a standard clock so that at any second which the operator chooses, one may be opened and another closed. Thus the flow for a definite period of time is led into a previously weighed receiver, which is then reweighed to give the mass of the water sample removed. Vapor left in the receiver line after shutting the receiver valve is captured in a trap immersed in liquid air, and is weighed.

By means of differential thermocouples which refer the temperature to a platinum resistance thermometer, observations of the virtually constant temperature of the calorimeter are made periodically during the experiment. Measurements of the potential drop and current in the electric heater are also made periodically.

[1] Publication approved by the Director of the Bureau of Standards of the U. S. Department of Commerce.

[2] Physicist, Bureau of Standards.

[3] Associate Physicist, Bureau of Standards.

[4] MECHANICAL ENGINEERING, vol. 51 (1929), p. 125.

To assure that the vapor removed is dry saturated, measurements are made with different rates of flow of the vapor from the calorimeter, because if priming occurs, its effect should vary with the rate of evaporation.

In exhibiting the results of the calorimetric measurements, the property of water which is most convenient as a background for analysis and tabulation is the heat content, also known as total heat, or enthalpy.

In this calorimeter the experimental determinations of heat capacity of a sample of water give as a result in international joules the increase in the quantity $H - Lu/(u' - u)$ over the observed range of temperature, in which H and L denote respectively heat content of saturated liquid and heat of vaporization per unit mass, and u and u' denote specific volume of saturated liquid and vapor, respectively.

TABLE 1 RESULTS OF CALORIMETRIC MEASUREMENTS AT SATURATION LIMIT

(Bureau of Standards, Nov. 30, 1929)

Temp., deg. cent.	$H - L\frac{u}{u'-u}$ (α)	Number of α experiments	$L\frac{u}{u'-u}$ (β)	Number of β experiments	$L + L\frac{u'}{u'-u}$ (γ)	Number of γ experiments
	(International joules per gram)					
10	41.99	13	(0.02)	..	.....	..
20	83.80	14	(0.04)	..	.....	..
30	125.51	13	(0.07)	..	.....	..
40	167.22	13	(0.12)	..	.....	..
50	208.93	12	(0.20)	..	.....	..
60	250.61	12	(0.31)	..	.....	..
70	292.30	14	(0.47)	..	.....	..
80	333.99	13	(0.70)	..	.....	..
90	375.67	13	(1.00)	..	.....	..
100	417.36	32	(1.40)	..	2258.75	11
110	459.04	18	1.95	2	.....	..
120	500.72	16	2.61	4	.....	..
130	542.39	15	3.49	4	2177.27	22
140	584.10	11	4.56	4	.....	..
150	625.81	11	5.92	4	2119.94	16
160	667.51	10	7.52	2	.....	..
170	709.23	10	9.47	2	2058.80	17
180	750.93	10	[11.78]	..	.....	..
190	792.58	10	[14.53]	..	.....	..
200	834.24	13	17.79	10	1957.89	14
210	875.74	23	[21.57]	..	.....	..
220	917.13	15	26.03	2	1883.13	26
230	958.47	15	31.20	2	.....	..
240	999.77	15	37.22	4	.....	..
250	1041.01	14	43.96	2	1758.76	5
260	1082.14	14	51.92	2	.....	..
270	1123.20	13	60.85	11	1664.90	25

L = heat of vaporization.
u = specific volume of saturated liquid.
u' = specific volume of saturated vapor.
Values in brackets are interpolated. Values in parentheses are calculated from Mollier's 1927 tables. All other values are observed.

TABLE 2 PROPERTIES OF WATER AT SATURATION LIMIT DERIVED FROM CALORIMETRIC MEASUREMENTS

(Bureau of Standards, Nov. 30, 1929)

Temp., deg. cent.	Heat content of liquid H	Heat content of vapor H'	Heat of vaporization L	Specific-volume ratio $\frac{u'}{u}$	Entropy of liquid ϕ	Entropy of vapor ϕ'
	—International joules per gram—				Int. joules per gram per deg. cent.	
0	0.00	....	....		0.0000	....
10	42.01	....	....	....	....	....
20	83.84	....	....	....	.....	....
30	125.58	....	....	....	0.4364	....
40	167.34	....	....	....	.....	....
50	209.13	....	....	....	0.7032	....
60	250.92	....	....	....	.....	....
70	292.77	....	....	....	0.9543	....
80	334.69	....	....	....	....	....
90	376.67	.....	.....	.....	.....	.....
100	418.76	2676.11	2257.3	....	1.3061	7.3558
110	461.0	....	....	....	....	....
120	503.3	.....	.....	.....	.....	.....
130	545.9	2719.7	2173.8	624	1.6336	7.0264
140	588.7	.....	.....	.....	.....	.....
150	631.7	2745.8	2114.0	358	1.8408	6.8360
160	675.0	....	....	....	....	....
170	718.7	2768.0	2049.3	217.4	2.0408	6.6637
180	762.7	....	....	....	....	....
190	807.1	.....	.....	.....	.....	.....
200	852.0	2792.1	1940.1	110.0	2.3298	6.4295
210	897.3	....	....	....	....	....
220	943.2	2800.3	1857.1	72.33	2.5167	6.2837
230	989.7	....	....	....	....	....
240	1037.0	.....	.....	.....	.....	.....
250	1085.0	2799.8	1714.8	40.00	2.7919	6.0709
260	1134.1	....	....	....	....	....
270	1184.0	2788.1	1604.0	27.36	2.9740	5.9259

In the latent-heat experiments we measure in international joules the energy which is added when unit mass of water is evaporated and withdrawn as saturated vapor at constant temperature. This amount of energy per unit mass is equal to $L + Lu/(u' - u)$. The ratio $u/(u' - u)$ is the fraction of a unit mass evaporated, but remaining within the calorimeter when unit mass is withdrawn.

The quantity $Lu/(u' - u)$ is complementary both to the determinations of heat capacity or constant-mass experiments, and to the determinations of heat of vaporization or vapor-withdrawal experiments when the values of H and L are desired. This quantity is measured conveniently at any desired temperature by observing in supplementary calorimetric experiments the energy required to produce the necessary evaporation when a certain quantity of saturated liquid is withdrawn.

Thus the three different types of experiment yield values in international joules of three quantities, referred to certain temperatures. These quantities,

$$H - L\frac{u}{u'-u}, \qquad L + L\frac{u}{u'-u}, \quad \text{and} \quad L\frac{u}{u'-u},$$

are denoted by the symbols, α, γ, and β. From these are derived finally the values of heat content of saturated liquid H, heat content of saturated vapor H', and heat of vaporization L. In addition to these three energy quantities, characteristic of the fluid, there also may be derived from the calorimetric data the ratio of the specific volumes and the entropy of the saturated liquid and vapor.

The results of experimental work completed are given in Table 1, together with the numbers of experiments performed to establish each value given.

The properties of water at the saturation limit which may be derived from the calorimetric data are given in Table 2. The formulas by which these derivations are made are as follows:

$$H = \alpha + \beta$$
$$H' = \alpha + \gamma$$
$$L = \gamma - \beta$$
$$\frac{u'}{u} = \frac{\gamma}{\beta}$$
$$\phi = \int \frac{\alpha dT}{T^2} + \frac{H}{T} = \int \frac{d\alpha}{T} + \frac{\beta}{T}$$
$$\phi' = \phi + \frac{L}{T}$$

in which

H = heat content of saturated liquid ($\epsilon + \pi u$)
H' = heat content of saturated vapor
L = heat of vaporization ($H' - H$)
u = specific volume of saturated liquid
u' = specific volume of saturated vapor

$$\left.\begin{aligned} \alpha &= H - L\frac{u}{u'-u} \\ \beta &= L\frac{u}{u'-u} \\ \gamma &= L + L\frac{u'}{u'-u} \end{aligned}\right\} \text{measured quantities}$$

T = temperature in degrees centigrade absolute
ϵ = internal energy
π = vapor pressure at saturation limit
ϕ = entropy of saturated liquid
ϕ' = entropy of saturated vapor.

From a consideration of the magnitude of the accidental and systematic errors in the determination of H, H', and L, it is estimated that the value of each of these tabulated quantities is within 1 part in 2000 of the true value.

The values of heat of vaporization may be represented in the range of the measurements within 1 part in 2500 by the empirical equation—

$$L = 0.00258\ (374 - \theta)^2 - 5.8863\ (374 - \theta) + 249.9\ (374 - \theta)^{1/2} - 113\ (374 - \theta)^{1/4}$$

where θ denotes degrees centigrade. The form of this equation has been chosen with regard to the usually accepted belief that at the critical temperature (374 deg. cent.) the heat of vaporization becomes 0 and approaches this value at a negative infinite rate, and that no real values exist at higher temperatures. This equation fulfils these conditions and fits the observed values between 100 deg. cent. and 270 deg. cent. to about the order of accuracy of the measurements.

For temperatures below 100 deg. the values calculated from the equation appear to agree satisfactorily with the experiments recorded in the literature. Some of the comparisons in this region are difficult to make because of the confusion of units involved.

The ratios of the specific volumes are obtained as the quotients of two directly measurable calorimetric quantities. These values are measured at saturation and quite independently of any volume observations. The accuracy of the ratios increases with rising temperatures because of the magnitude of the quantities involved.

For the calculation of entropy two empirical equations for α were used, one fitting the data between 0 deg. cent. and 150 deg. cent., and the other between 100 deg. cent. and 270 deg. cent. Using these equations and performing the operations indicated by either formula given above for calculating entropy, numerical values for the change in entropy were computed. The agreement in the overlapping range was satisfactory.

For the purpose of guidance in the choice of values to be used in formulation, a discussion of results from various experimental sources is useful in so far as it exhibits facts which help in making an appraisal of the reliability of the data. This is a very different matter from the simple device of showing graphically the deviations of the various published data from some group taken as a reference basis. There is very great difficulty in making reliable comparisons of previously published calorimetric data on fluids. One reason for this is that calorimetric units have heretofore been in such a state of confusion that only the most scrupulous care on an author's part in describing his standards and the units employed enables the reviewer to refer the values to a common basis. Another reason is the uncertainty as to just what physical quantity the author measured, and here again, as in the case of standards and units, the lack of careful theoretical analysis and definition of the processes utilized in the determinations may lead to erroneous or conflicting interpretation of the results.

It is not surprising that a number of cases have occurred in the formulation of steam tables where question may arise as to interpretation of the published data. Two examples will be mentioned here for illustration. The first case is that of Dieterici's[5] measurements of the heat capacity of liquid water, which in the region above 100 deg. cent. have been regarded as the most important direct experimental data. His results expressed as mean specific heats from 0 deg. to the stated temperature have usually been interpreted as expressing the change in heat content. Callendar[6] has mentioned the fact that Dieterici's results express the change of intrinsic energy from 0 deg. to the observed temperature under saturation pressure. This appears to have escaped other reviewers, which probably accounts for a considerable part of the disparity between existing steam tables. Even within the last year in a comparison[7] of Dieterici's results with those of the Bureau of Standards this has very naturally been overlooked, making an error of about 1 per cent of the heat content at 270 deg. cent. in this comparison.

Another case is that of Smith's[8] determination of the heat of vaporization of water at about 100 deg. cent. This determination has been regarded as one of the most reliable for use as a connecting link between the liquid and the vapor boundaries. Smith's work shows evidence of very great care in attention to experimental details. In particular his method of evaporating water quietly in a stream of air to avoid the entrainment of particles of liquid in the steam removed, which was the suspected cause of too low results in most of the previous work, was ingenious, and apparently effective. However, no data are given in Smith's paper to show that the partial pressure of the vapor diluted with air was equal to saturation pressure at the observed temperature. If there were expansion of the vapor after evaporation, his measurement included in addition to the heat of vaporization the increase of the heat content of the vapor from saturation pressure down to the partial pressure of the vapor diluted with air.

In order to take account of this effect it would be necessary to know the relative mass flow of both air and water vapor. It may be that this information may be supplied by Professor Smith and that the correction will be found negligible. But at present it is impossible to make a complete reduction of the results. Whatever may be the consistency and precision of the measurements, we are still unable to appraise the absolute accuracy of the result until information can be obtained which will determine the state of the vapor as it left the calorimeter.

In the two cases cited above the efforts on the part of the experimenters to obtain essential physical facts deserve our warmest admiration, as do likewise the endeavors of the reviewers to put them to practical use, and the ambiguities which exist may fairly be blamed to the obscurity surrounding calorimetry of saturated fluids. However, they illuminate the difficulties with which builders of steam tables have had to cope, and emphasize the need for additional comprehensive and systematic measurements as well as careful study of previous measurements to establish the physical facts as to just how steam behaves.

With the presentation of the results here given it is hoped that the need for a reliable, thorough, and coherent calorimetric survey of the behavior of water over a limited portion of the saturation region has been met. No such comprehensive survey has ever before been completed. The experimental evidence of its reliability is too extensive to find a place in this report, but will be forthcoming in the next few months. Mention has been made of the danger of erroneous conclusions from reviews of previously published experimental work. The authors therefore purposely defer for the present any specific comparisons with such source data or with any steam-table formulations which have yet appeared.

[5] *Annalen der Physik*, vol. 6, 4th series (1905), p. 593.

[6] Callendar, "Properties of Steam," 1920, p. 28.

[7] Davis and Keenan, "Recent Research on the Thermal Properties of Steam," MECHANICAL ENGINEERING, vol. 51 no. 12, Dec., 1929, p. 922.

[8] *Physical Review*, vol. 33 (1911), p. 173.

The group of values of properties of water obtained by this strictly calorimetric method constitutes, within experimental limits, a survey of the behavior of the fluid at the saturation limit which is thermodynamically consistent. This skeleton table of basic values establishes the calorimetric behavior of saturated liquid water and saturated water vapor within our experimental limits, and is offered as an independently established base or reference datum to which other groups of properties of the fluid determined in the superheat region may be referred, and as a suitable foundation for a later and greater formulation.

Extension of the range of the determinations of heat capacity and heat of vaporization above 270 deg. cent. has been temporarily suspended to make way for another type of measurement beginning again at lower temperatures. This fourth type is expected to yield a survey of the heat content of superheated vapor in the region adjacent to the saturation limit. In the proposed method the saturated vapor is throttled to a low pressure and reheated to its original temperature before its withdrawal to determine the heat content in this superheated state. The proposed method is to throttle the saturated vapor isothermally within the calorimeter before its withdrawal to determine the heat content. These throttling experiments will be attempted as soon as the necessary changes in the apparatus have been completed.

It will be necessary to know the pressure as well as temperature for this measurement, and to this end a pressure-measuring apparatus is being added to the auxiliary equipment already in use. Since the state of the stirred fluid in the calorimeter seems ideal for vapor-pressure measurements, it is hoped that data of some value on this property will be obtained.

It is possible that within the coming year some progress will be made on the design and construction of a flow calorimeter for the accurate survey of the heat content of superheated steam beyond the scope of the present apparatus. Such a survey has been recommended for three principal reasons: namely, (1) Because there are now certain ranges which have never been investigated; (2) because there are divergent data in the other ranges; and (3) because the data in the superheat as well as those at saturation must be correlated by a set of comprehensive experiments of this sort, before a truly consistent steam table can be evolved. It is with this end in view that the investigations at the Bureau of Standards are to be pushed forward, looking ahead toward the time when the properties of steam will be known with a generally acceptable degree of finality.

Comparisons

BY J. H. KEENAN,[1] HOBOKEN, N. J.

THE extraordinary activity of the past decade in the field of steam research has radically altered the state of knowledge of the properties of steam. Figs. 1 and 2 show the extent to which the large gaps that existed in our experimental knowledge of steam in 1921 had been filled in by 1929. Fig. 2 does not chart the data presented at the December meeting of the A.S.M.E. or the work most recently completed in Germany. The new M.I.T. specific-volume measurements superimpose on the higher-pressure portion of the Harvard measurements; the Bureau of Standards has produced latent-heat measurements extending from atmospheric pressure to the upper limit of their liquid data; and Dr. Jakob in Germany reports at least tentative values of latent heat to as high as 310 deg. cent. (590 deg. fahr.), leaving very little of the two-phase region unexplored. We are approaching the happy state where a chart of the nature of Fig. 2 will involve so much overlapping as to be more confusing than instructive.

This experimental activity has already had a marked effect on steam-table characteristics. The values for the total heat of saturated vapor tabulated by the various steam tables may be used as a rough measure of the agreement or disagreement between them. Fig. 3 compares this property as taken from the various tables in existence about 1921. Fig. 4 shows how effectively the new experiments are working toward international agreement. The characteristics of this quantity and to a large extent its magnitudes have in eight years converged amazingly.

It is always interesting to compare newly published experimental data with similar measurements from a different source or with values deduced, however indirectly, from measurements of an entirely different kind.

Fig. 5 compares the various latent-heat measurements at present available with the steam table that is about to be published. In order to exaggerate the scale, differences are plotted from an arbitrarily chosen chord of the latent-heat curve.[2] The means by which the table values were determined were given in detail a year ago.[3] Suffice it to say here that they were based on the Harvard Joule-Thomson measurements, the Knoblauch specific-heat determinations, the Bureau of Standards liquid total heats as then published, and the M.I.T. volume measurements at high pressures. They are in a sense a composite picture of all those sources. It is interesting to note, however, that at the time the table was developed no reliable experimental data existed in the superheat region between 565 lb. per sq. in. and 1350 lb. per sq. in., and those in existence outside these limits furnished information on latent heats only in a very indirect manner. The only available experiments on latent heat were those of Henning, extending to 145 lb. per sq. in., and two tentative values published by Jakob at 145 lb. per sq. in. and 277 lb. per sq. in. The definitive Jakob values since published differ from the tentative values in the direction which brings them into closer agreement with the table.

The Jakob values from 250 to 310 deg. cent. shown in Fig. 5 were very graciously transmitted to me by Dr. Jakob a week before the December, 1929, meeting of the A.S.M.E. They are the observed values, not smoothed, and are probably subject to revision at the higher temperatures.

In this issue Mr. Osborne is publishing for the first time the Bureau of Standards measurements of latent heat (see Fig. 5) extending from 100 deg. cent. to 270 deg. cent. (14.7 lb. per sq. in. to 800 lb. per sq. in.). The atmospheric-pressure measurement agrees extremely well with the Henning and Carlton-Sutton measurements and coincides within 0.02 cal. per gram with the table value which was chosen almost two years ago. Above atmospheric pressure these measurements verify Hen-

[1] Assistant Professor of Mechanical Engineering, Stevens Institute of Technology. Jun. A.S.M.E.

[2] Ordinate of chord (int. cal. per gram) = 596.57 − t, where t = temperature, deg. cent.

[3] MECHANICAL ENGINEERING, vol. 51, no. 2, Feb., 1929, pp. 109–115.

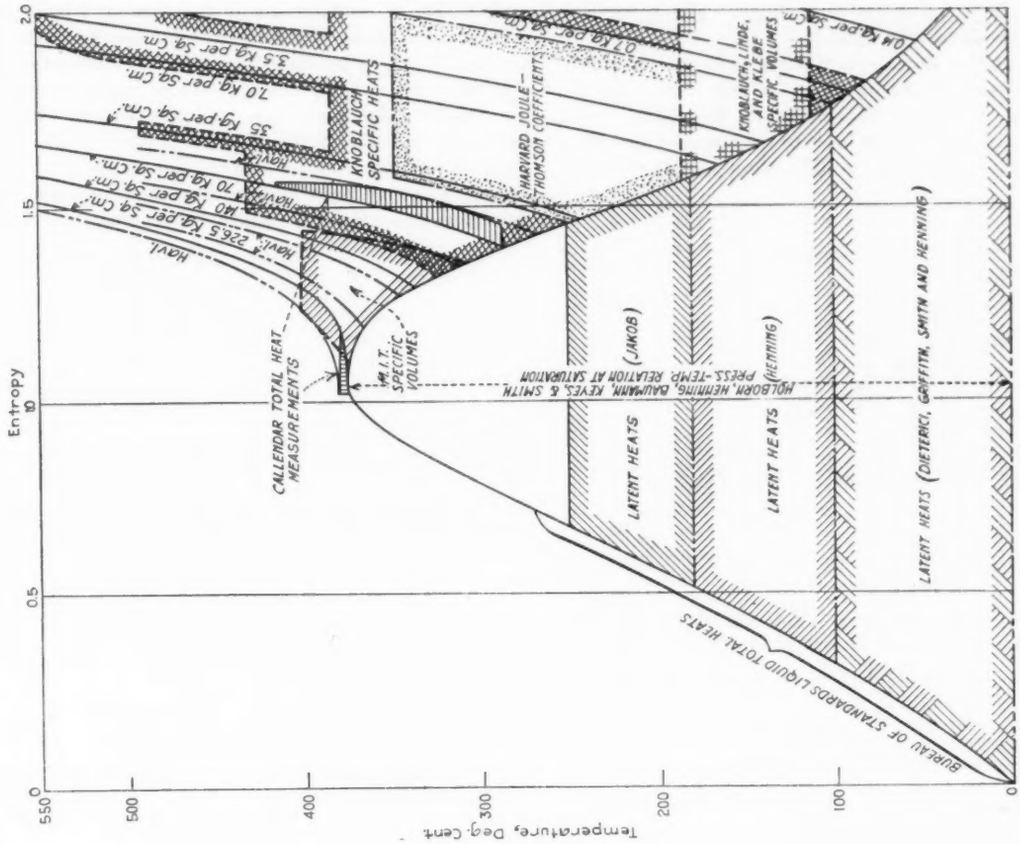

Entropy
Temperature, Deg. Cent.
BUREAU OF STANDARDS LIQUID TOTAL HEATS
LATENT HEATS (DIETERICI, GRIFFITH, SMITH AND HENNING)
LATENT HEATS (HENNING)
LATENT HEATS (JAKOB)
HOLBORN, HENNING, BAUMANN, KEYES, & SMITH PRESS.-TEMP. RELATION AT SATURATION
M.I.T. SPECIFIC VOLUMES
CALLENDAR TOTAL HEAT MEASUREMENTS
HARVARD JOULE-THOMSON COEFFICIENT
KNOBLAUCH, LINDE, AND KLEBE SPECIFIC VOLUMES
KNOBLAUCH SPECIFIC HEATS
0.14 Kg. per Sq. Cm.
0.7 Kg. per Sq. Cm.
3.5 Kg. per Sq. Cm.
10 Kg. per Sq. Cm.
35 Kg. per Sq. Cm.
70 Kg. per Sq. Cm.
140 Kg. per Sq. Cm.
226.5 Kg. per Sq. Cm.
Havl.

FIG. 2 TEMPERATURE-ENTROPY DIAGRAM SHOWING THE EXTENT OF VARIOUS RESEARCHES IN 1929

(The lines marked "Havl." are the pressures along which Havlicek is measuring total heats.)

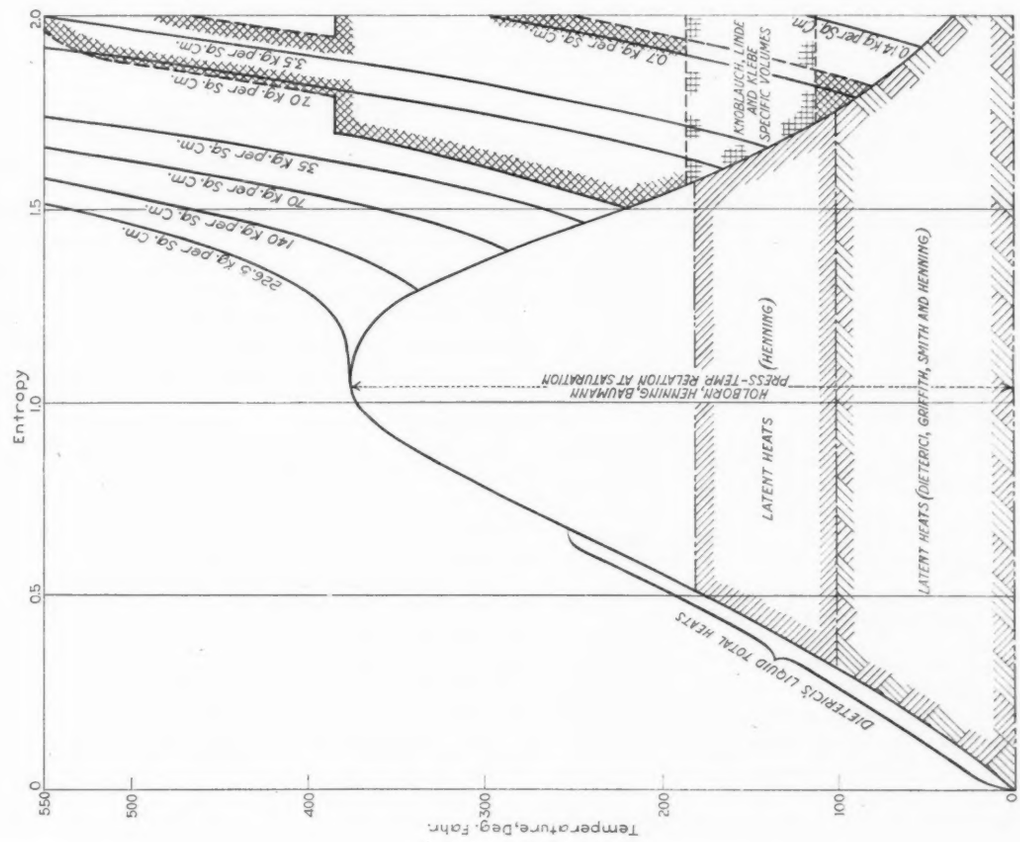

Entropy
Temperature, Deg. Fahr.
DIETERICI'S LIQUID TOTAL HEATS
LATENT HEATS (DIETERICI, GRIFFITH, SMITH AND HENNING)
LATENT HEATS (HENNING)
HOLBORN, HENNING, BAUMANN PRESS.-TEMP. RELATION AT SATURATION
KNOBLAUCH, LINDE AND KLEBE SPECIFIC VOLUMES
0.14 Kg. per Sq. Cm.
0.7 Kg. per Sq. Cm.
3.5 Kg. per Sq. Cm.
10 Kg. per Sq. Cm.
35 Kg. per Sq. Cm.
70 Kg. per Sq. Cm.
140 Kg. per Sq. Cm.
226.5 Kg. per Sq. Cm.

FIG. 1 TEMPERATURE-ENTROPY DIAGRAM SHOWING THE EXTENT OF THE VARIOUS RESEARCHES

(Status in 1921.)

ning's work and improve on its consistency. The agreement with Jakob is excellent throughout.

Both Jakob and the Bureau of Standards begin to depart slightly from the table values at about 250 deg. cent. (570 lb. per sq. in.). Fig. 6 shows the Bureau of Standards liquid measurements departing from the table in the opposite direction, and Fig. 7 illustrates how these two differences have practically

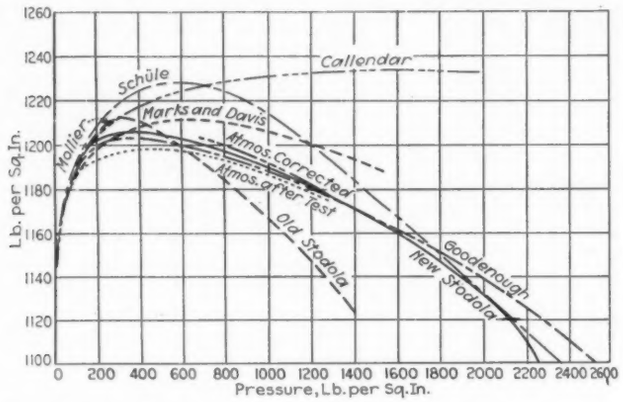


FIG. 3 TOTAL HEAT OF SATURATED VAPOR AS GIVEN BY THE VARIOUS STEAM TABLES AND DIAGRAMS EXISTING IN 1921

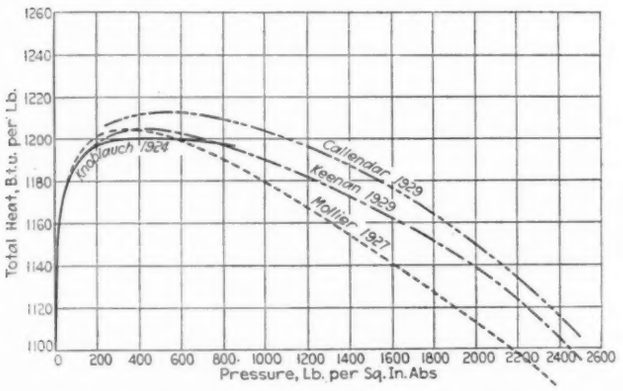


FIG. 4 TOTAL HEAT OF SATURATED VAPOR AS GIVEN BY RECENTLY PUBLISHED STEAM TABLES AND DIAGRAMS

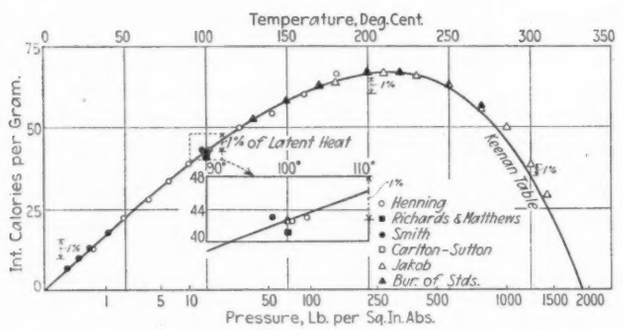


FIG. 5 COMPARISON OF MEASUREMENTS OF THE LATENT HEAT OF VAPORIZATION

cancelled each other in the summation, the total heat of saturated vapor. It is, perhaps, fortuitous that such close agreement should be found between direct measurements of the total heat of saturated steam and the values arrived at by a circuitous route which started with Joule-Thomson coefficients, specific-heat, specific-volume, and atmospheric latent-heat measurements.

The discrepancies shown in Fig. 5, and on an exaggerated scale in Fig. 6, could probably be eliminated by a very slight upward adjustment of the steam-table specific volumes on the saturated-vapor line, thus increasing the tabulated change in volume during vaporization and, as a consequence of the Clapeyron relation, the latent heat of vaporization. Unfortunately the new M.I.T. specific-volume measurements which were presented at the Annual Meeting fall below the table values instead of above as would be suggested by these latent-heat measurements. But Dr. Smith has emphasized the tentative

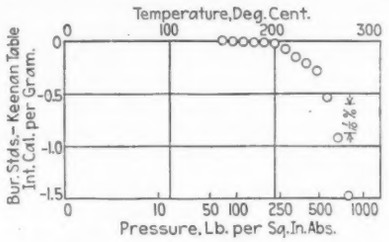


FIG. 6 DIFFERENCES BETWEEN BUREAU OF STANDARDS MEASUREMENTS OF LIQUID TOTAL HEATS AND KEENAN TABLES

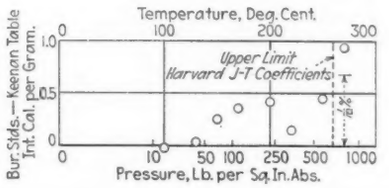


FIG. 7 DIFFERENCES BETWEEN BUREAU OF STANDARDS MEASUREMENTS OF SATURATED-VAPOR TOTAL HEATS AND KEENAN TABLES

nature of his new figures, and it is hoped that a review of them by the experimenters will result in values more consistent with the work of Jakob and Osborne.

An International Heat Unit

THE heat physicists who are seeking a more precise determination of the physical properties of steam, and who met in London last summer to compare and correlate their results, did one thing that will render their meeting memorable.

They adopted a unit of heat definable in terms of the simple relations of force, mass, and acceleration.

The calorie as newly defined is equivalent to 1-860th of a kilowatt-hour, instead of to the amount of heat required to raise the temperature of one kilogram of water one centigrade degree at some place or other in the scale. And it makes a difference which place.

The kilowatt as a measure of power is rapidly backing the horsepower, cheval, Pferdestärke, etc., off the map. Although it has come into use largely in connection with electrical machinery and applications, it is not electrical but mechanical in its derivation, definition, and significance.

One-860th of a kilowatt-hour represents a definite amount of energy whether it be applied as mechanical work to lifting water and creating pressure head or as heat to accelerating the molecules of a substance and creating temperature head.

Its adoption as the measure of the value of a calorie means the doing away with the necessity of laboratory determination in favor of expression in established physical units. And it means the passing of the "mechanical equivalent of heat" as an experimental relation between two independent units of energy.—F. R. Low in *Power*, December 17, 1929, p. 953.

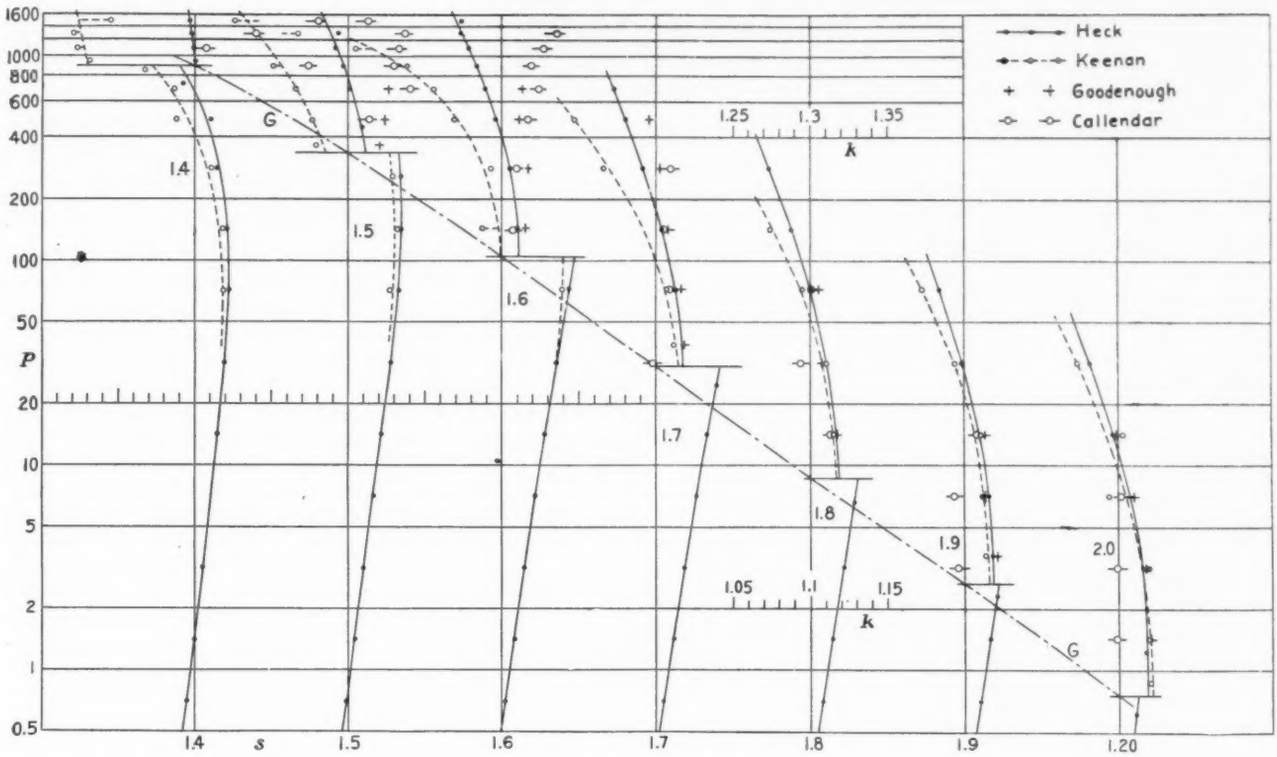


FIG. 1 PLOTS OF EXPONENT k

Notes on Formulation

BY ROBERT C. H. HECK,[1] NEW BRUNSWICK, N. J.

THIS paper presents two matters: the first an investigation of the pressure-volume form of the adiabatic of steam, leading to a general comparison of formulations; the second a discussion of the thermal properties of the liquid, along and behind the saturation line.

THE ADIABATIC OF STEAM IN p-v COORDINATES

As to the adiabatic, the question considered is the relation of the true curve to the gas equation pv^k = const. What is done is to fit a curve of this form to successive pairs of points of the isentrope, finding the value of exponent k for each interval. Since quantity pv can be handled much more effectively than simple volume v, the convenient relationship for routine calculation is

$$\frac{p_1v_1}{p_2v_2} = \left(\frac{p_1}{p_2}\right)^{\frac{k-1}{k}} \quad \ldots\ldots\ldots\ldots\ldots\ldots [1]$$

from which, with $\log p_1v_1 - \log p_2v_2 = \Delta \log pv$ and $\log p_1 - \log p_2 = \Delta \log p$,

$$k = \frac{\Delta \log p}{\Delta \log p - \Delta \log pv} \quad \ldots\ldots\ldots\ldots\ldots [2]$$

A sample calculation, made at $s = 1.6$, is as follows:

p	$\log p$	$\Delta \log p$	pv	$\log pv$	$\Delta \log pv$	Diff.	k
1000	3.00000		749.5	2.87477			
		0.09691			0.02138	0.07553	1.284
800	2.90309		713.5	2.85339			
		0.12494			0.02803	0.09691	1.290
600	2.77815		668.9	2.82536			
		0.17609			0.04024	0.13589	1.297
400	2.60206		609.7	2.78512			
		0.30103			0.07037	0.23066	1.305
200	2.30103		518.5	2.71475			

One purpose in finding index k might be to use it in calculating the p-v coordinates of the adiabatic curve. This could be done for superheated steam if k were constant, as it is sometimes assumed, but with variable k such use becomes impracticable. Rather, the usefulness of the investigation lies in the fact that if the various adiabatics are found to be similar in form it will then be much easier to generalize about such a matter as the dimensional form of the steam jet.

The scheme of Fig. 1, for showing results as to k, is as follows: The background is a trellis of vertical lines of constant entropy at $s = 1.4$ to 2.0 and of horizontal lines of constant pressure on a scale of log p. Up to $p = 400$ lb. abs. the step or stage ratio is either 2 or 2.5; above that the use of $\Delta p = 200$ makes $\Delta \log p$ decrease rapidly. The value of k for each pressure interval is plotted at midheight of the log intervals.

Each vertical carries its own group of curves, plotted to a scale of ten points of the value 0.01 between verticals. Below saturation curve GG the basic vertical is at 1.1 of k; above saturation it is at 1.3 of k, as appears on the scales shown at $s = 1.8$.

[1] Professor of Mechanical Engineering, Rutgers College. Life Mem. A.S.M.E.

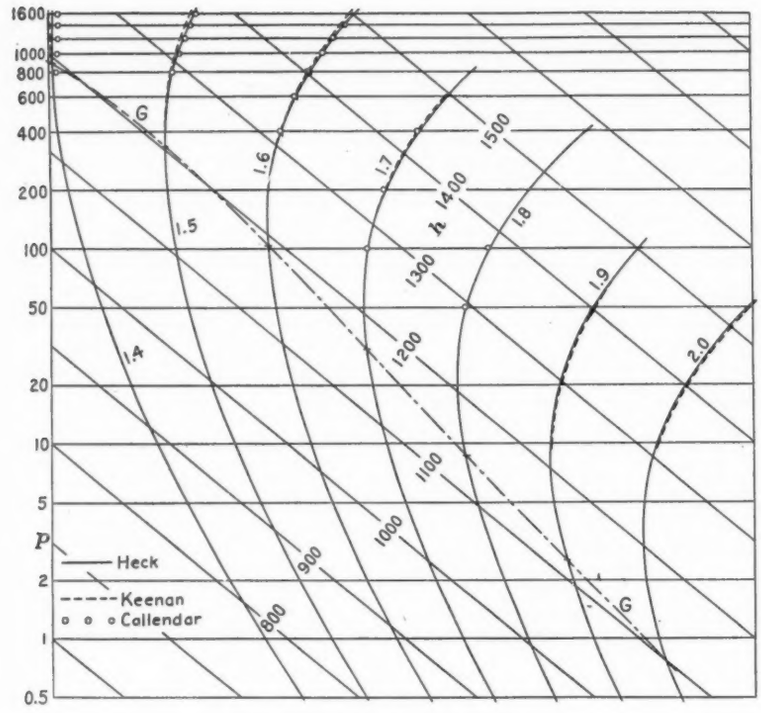


FIG. 2 ISENTROPES OF h ON p

In this and following comparisons my own steam equations of 1920 are given prominent place, having in large part just been computed for this purpose. Even with definite equations and a full command of the calculations it is difficult to avoid small irregularities that show up in erratic values of k. With volume to only three figures, as in several tables, the k-points scatter rather badly—remembering that Fig. 1 is a plot of the magnified ends of ordinates.

Next comes the new Keenan tabulation, not yet published, shown over full ranges except where it is indistinguishable in the wet-steam region. The Goodenough table, even less distinguishable below saturation, is shown over its full but shorter ranges. The Callendar formulation of 1924 appears only in the region of superheat, with some extensions down into supersaturation.

Below saturation the curves agree in a general way with the old Zeuner formula $k = 1.035 + 0.1\ x$; but there is a small systematic variation from close similarity, and at high pressures a decided swing to the left near saturation.

From saturation upward the outstanding features of the exhibit in Fig. 1 are as follows:

Heck: Start at saturation with $k = 1.32$ down to 1.30 as pressure is higher; swing to the left in rising and reach about 1.27 at the upper limit of 1000 deg. fahr.

Keenan: Same general form, but accentuated decrease with pressure rise along the saturation line and excessive swing to the left in rising, as seen most fully at $s = 1.6$; note the range around 1.23 for the short curve at $s = 1.4$.

Goodenough: Values somewhat erratic, but hold above 1.3; over the usual working range a fair mean would be 1.32 for k.

Callendar: Keeps close to 1.3 at low pressures or high entropies, then moves to the right, ranging around 1.36 at $s = 1.4$.

In view of the large discrepancies thus appearing, particularly in the high region of recent definition, it becomes desirable and necessary to go back to a more direct comparison of the formulations.

ISENTROPES IN h AND pv ON p

First the values of h and pv along the isentropes are shown in Figs. 2 and 3, still on the vertical base of log p but with inclined lines of constant h or pv. As a natural result of the manner of derivation of entropy s, including the fact of practically the same heat of liquid in all formulations, the curves show only small differences in Fig. 2: only with large differences in specific heat c_p do differences of any size begin to appear, in the region of superheat. Of course the steam-saturation line GG will be at different heights; notably, this Callendar curve lies far above the one here drawn, at the left-hand side of the diagram. There is no perceptible break in the h-adiabatic as it crosses saturation, in analogy to the similar continuity of the constant-pressure line where it crosses saturation in the Mollier chart.

In Fig. 3 the differences really take on size, especially at lower values of s or at higher pressures near to saturation. These differences can readily be related to those in k that are shown by Fig. 1, but to go into a detailed comparison now would take up too much time. To this last plot is added one showing out of the original Marks and Davis table, along $s = 1.7$.

DIRECT PLOTS OF h AND pv ON p

Coming now to direct plots, in terms of the steam-table quan-

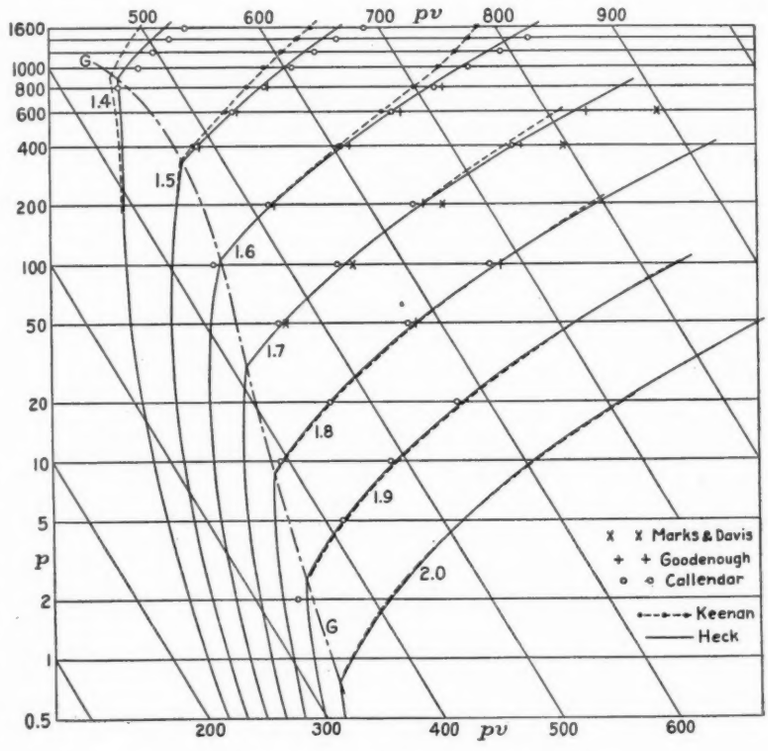


FIG. 3 ISENTROPES OF pv ON p

ities, we have isotherms of h on p in Fig. 4 and of pv on p in Fig. 5. In total heat h the discrepancies are greatest at 600 deg. and have become small at 900 deg.; in bulk measure pv they are both larger and more persistent. Note on each diagram the showing of one per cent of total quantity at each vertical.

To the isotherms in Fig. 5 are added three sets of isentropes; and in both kinds of curves there is a rather excessive difference between the Keenan and the Heck formulations. Comment that might be made upon the Callendar showing is forestalled by the fact that this older formulation has recently been modified in the direction of the results found by other experimenters. In any case, the present purpose is to exhibit rather than to discuss.

In these two plots are shown the latest data for saturated steam, the results of Jakob and Fritz at the Reichsanstalt, just published. It is their final, smoothed-out results as to heat of vaporization and specific volume that appear, from 200 to 250 deg. cent. The latent heats are backed by the generally accepted heats of liquid up to 500 deg. fahr.

My own reactions to this study are these:

1 A strengthened feeling of the importance of the specific-volume measurements that are now coming in, with a desire that they may be given the widest range possible. In this field it is a fortunate and helpful fact that the quantity measured is one of relatively large variation, so that extreme precision is not quite so requisite as in heat measurements. As seen in Figs. 4 and 6, the change in volume during superheating, relative to saturation volume, is much larger than the change in total heat during superheating, relative to saturation total heat.

2 A lack of complete confidence in the small specific volumes found by Keenan. The trend that these show may be correct, but it needs to be fully established by direct measurements.

The Liquid Line and Behind It

This title refers to the saturation line of the liquid and to the general behavior of the liquid in its region of subsaturation. For a complete formulation of water in that region the data are not yet available, therefore the illustrative diagrams now to be given are based dimensionally upon the properties of CO_2, which are known with a good degree of accuracy.

Consider the saturation line of the liquid, curve *FF* in Fig. 6, rising from the melting or freezing point *M* but not shown so high as the critical pressure of 1080 lb. This is a simple pressure-volume diagram, and the product pv which increases up *FF* is a portion of the total heat of the liquid, as that would be given in a table of the properties of the substance.

Take the definition, total heat h equals internal energy u plus product pv (converted to heat units by factor A) or $h = u + Apv$, and by differentiation get—

$$dh = du + Apdv + Avdp \quad \ldots\ldots [3]$$

From the general energy equation, that heat received equals increase of internal energy plus outer work performed,

$$dq = du + Apdv \quad \ldots\ldots [4]$$

then

$$dh = dq + Avdp, \quad \text{or} \quad dq = dh - Avdp \quad \ldots\ldots [5]$$

Suppose that the curve of heat of liquid h_f has been established

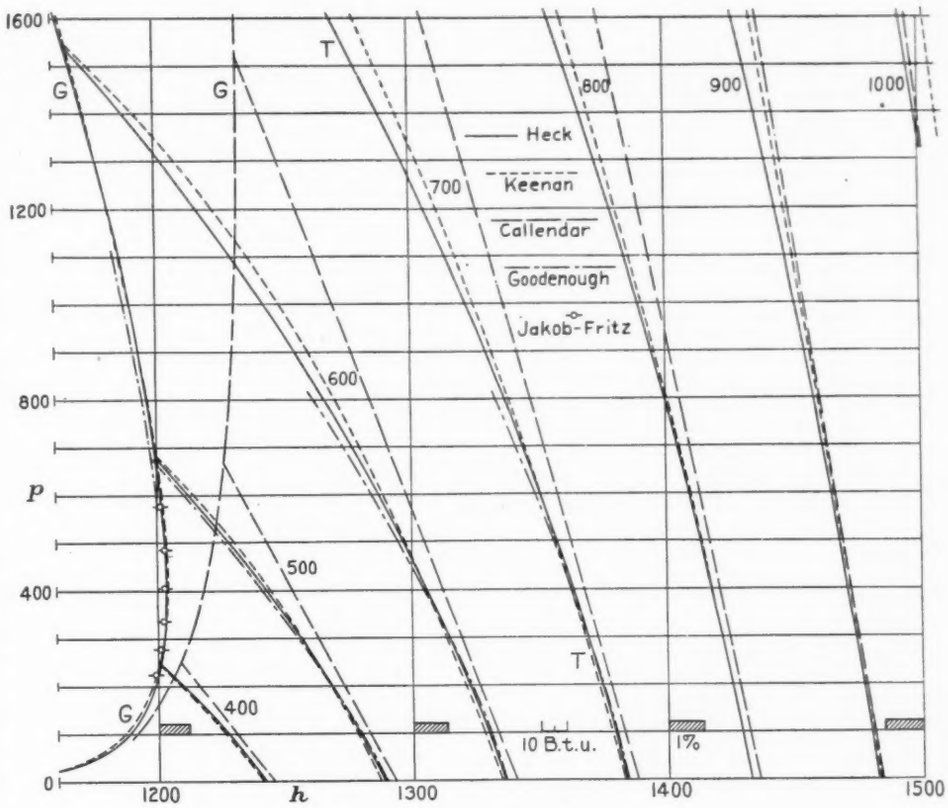


FIG. 4 DIRECT PLOT OF h ON p

on a base of temperature t, as it is regularly given in one of the tables for the saturated state, and that from it the temperature-entropy or T-s curve or column is to be derived by step integration. From $dq = Tds$ or $\Delta q = \Delta Ts$,

$$\Delta s_f = \frac{\Delta q}{T} = \frac{1}{T}\left(\Delta h + Av\,\Delta p\right) \quad \ldots\ldots [6]$$

Values of $Av\,\Delta p$ are indicated in Fig. 6, by drawing horizontals at intervals of 10 deg. cent.

During the passage from state *A* to state *B* in Fig. 6 the product pv increases from area *OCAE* to area *ODBG*. Equation [6] means that the portion *ABGE* of this increase is a component of Δq or of $T\Delta s$, to be included in the area beneath curve *FF* in the T-s diagram, Fig. 11, but that area *ABDC* is outside of Δq or $T\Delta s$. Note the size of the shaded square that represents 0.1 centigrade heat unit in Fig. 6.

The general behavior of the liquid is shown by the constant-pressure curves in Fig. 7 and the isotherms in Fig. 8. The p-constant lines, each marked with its pressure in pounds per square inch, lie below saturation curve *FF*. Up to $p = 1080$ they rise to and (for the liquid phase) end in this saturation curve. A

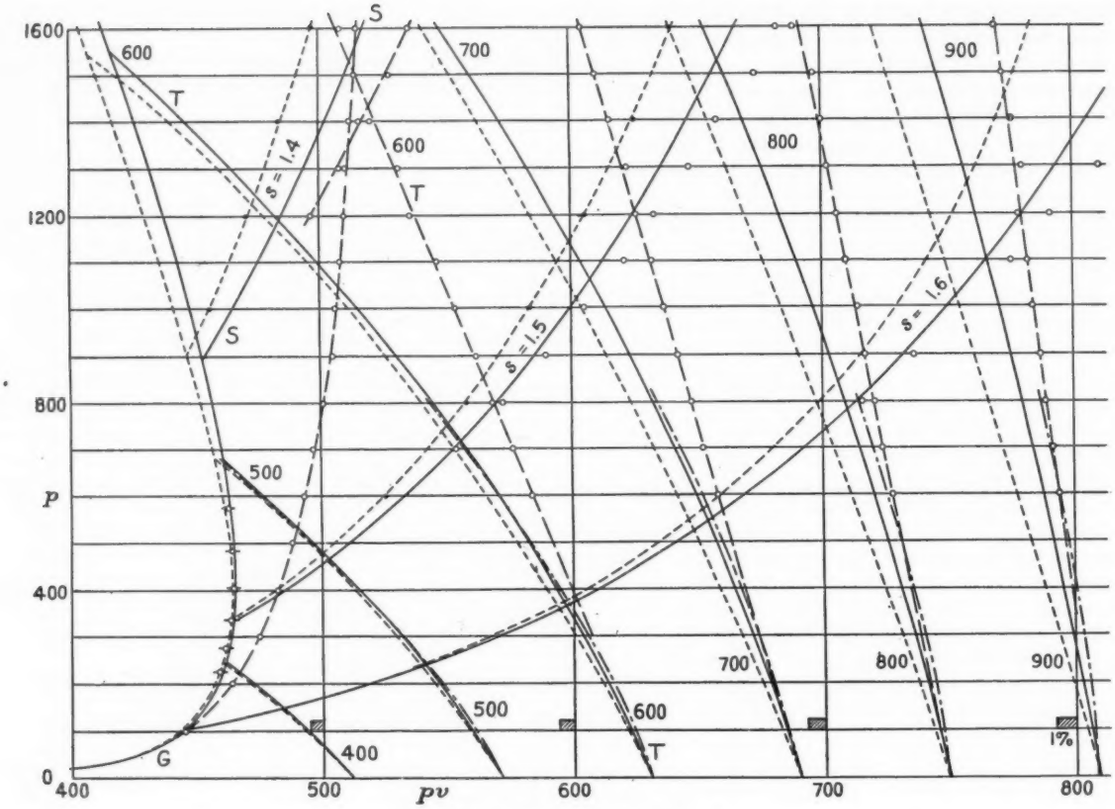


FIG. 5 DIRECT PLOT OF pv ON p

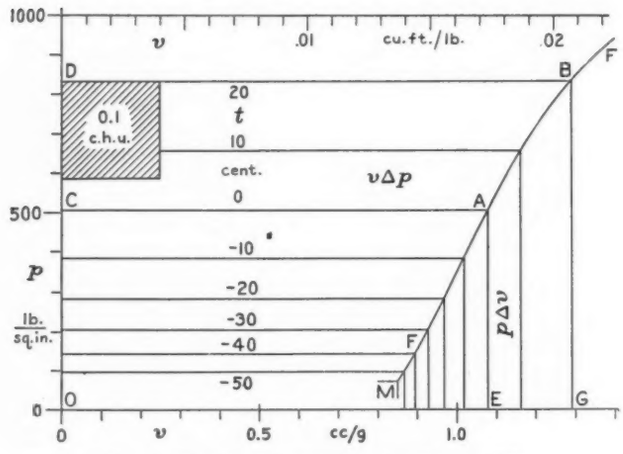


FIG. 6 THE SATURATION LINE OF LIQUID CO_2

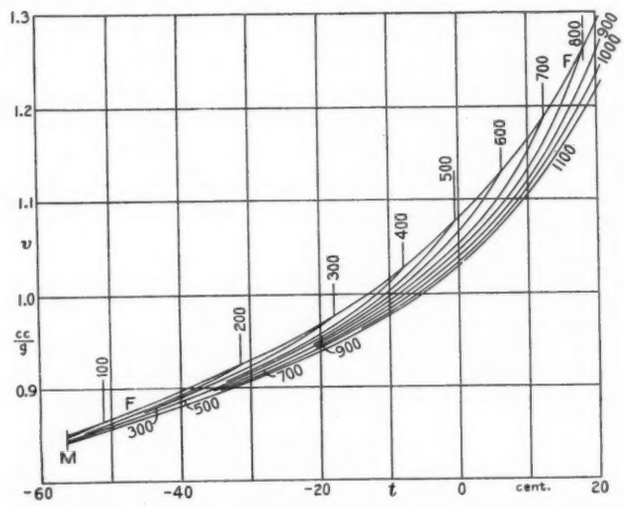


FIG. 7 CONSTANT-PRESSURE CURVES OF LIQUID CO_2

notable fact is the rapid increase (with temperature) of the rate of expansion dv/dt, or of the slope of these curves.

The same rapid growth of the coefficient of dilatation dv/dt appears in Fig. 8, in the wider spacing of the isotherms as temperature is higher. These curves, of form AB, rise from saturation line FF with a compression of the liquid which is small at low temperatures but considerable at high temperatures and toward the critical point.

Now during an isothermal compression AB, Fig. 8, heat would have to be abstracted equivalent to the work $EABG$ or $\int pdv$ done upon the liquid and to the decrease of internal energy, which is $\Delta u = u_a - u_b$. If we can measure or find the value of Δq from A to B, and then deduct from it the heat-unit value of area $EABG$, we shall have the energy change Δu.

Before seeking quantity Δq let us note the relation of Fig. 8 to Equation [3]. Area $EABG$ is the integral of pdv, functioning as a part of Δq, and area $CABD$ is the integral of vdp. Overlapping in "triangle" ABH these have their (algebraic) sum in

$$CHBD - EAHG - OGBD - OEAC = (pv)_b - (pv)_a$$

and with $u_b - u_a$ this makes up the difference $h_b - u_a$, as it should under the definition of enthalpy h as $u + Apv$.

HEAT TRANSFER ALONG THE ISOTHERM

Just as we go to the T-s chart in order to find the imparted heat Δq in an isothermal expansion of superheated steam, so also

it is most convenient to get Δq for the compression AB in Fig. 8 by establishing an entropy quantity. For this the underlying general relationship (one of Maxwell's equations) is

$$\left(\frac{ds}{dp}\right)_t = -A\left(\frac{dv}{dt}\right)_p \quad \ldots\ldots\ldots\ldots\ldots\ldots [7]$$

which means that the rate of change of entropy along the isotherm is a simple function of the rate of expansion under constant pressure.

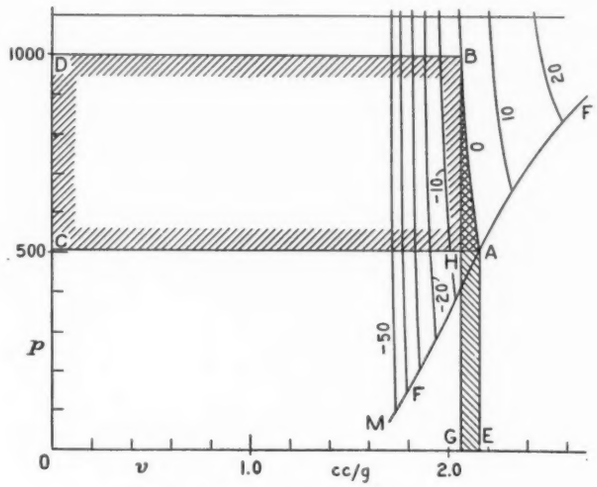


FIG. 8 ISOTHERMS OF LIQUID CO_2

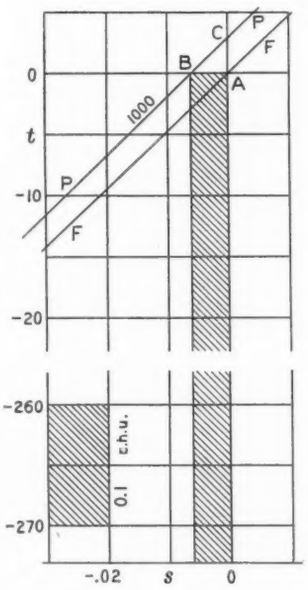


FIG. 10 ISOTHERMAL AND ADIABATIC OF THE LIQUID

Data for the use of Equation [7] might be taken from Fig. 7: at a vertical line of constant t the slope of each p-constant curve could be found, and then these values of $(dv/dt)_p$ be plotted on p as base; and a planimeter measurement of area beneath the curve would give a value of the integral in

$$\Delta s_t = -A\int_{p_1}^{p_2}\left(\frac{dv}{dt}\right)_p dp \quad \ldots\ldots\ldots\ldots [8]$$

This integral can also be found graphically from Fig. 9 directly. Here the useful portion of Fig. 8 is enlarged, and we reason in regard to the shaded area as follows:

Between two isotherms, at interval Δt, the distance HK is Δv, so that—

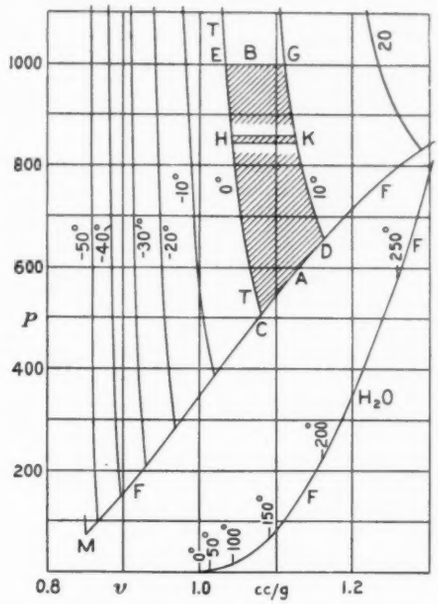


FIG. 9 ENLARGED PORTION OF FIG. 8, ALSO THE p-v SATURATION CURVE OF LIQUID H_2O

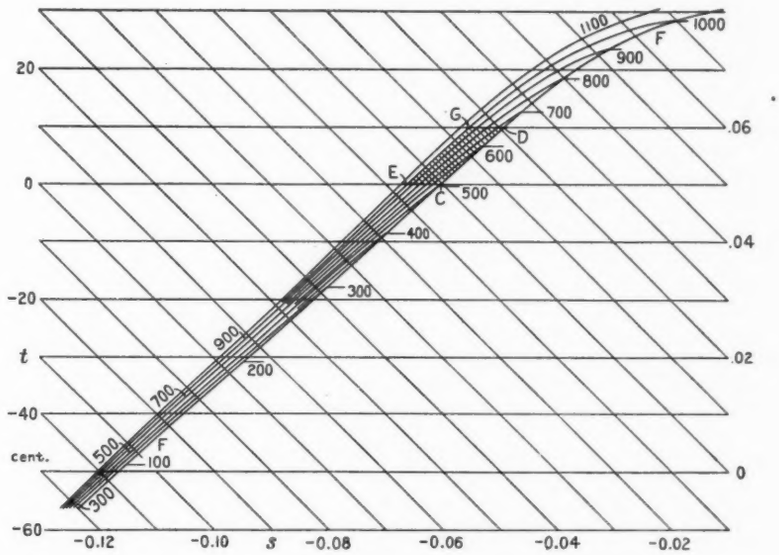


FIG. 11 CONSTANT-PRESSURE LINES IN THE TEMPERATURE-ENTROPY DIAGRAM

$$\frac{\Delta v}{\Delta t} = \text{mean}\left(\frac{dv}{dt}\right)_p \quad \ldots\ldots\ldots\ldots\ldots [9]$$

is the average rate of expansion over this interval and at the particular pressure. As a working approximation assume this mean to be exact at the mean temperature, here 5 deg. cent. Then with the width HK or Δv and the depth dp the area of the small shaded element is—

$$\Delta v dp = \Delta t \left(\frac{dv}{dt}\right)_p dp \quad \ldots\ldots\ldots\ldots\ldots [10]$$

Integrating this $\Delta v dp$ by planimeter measurement of the whole area *CEGD*, and then dividing it by Δt (in this case, 10 deg.),

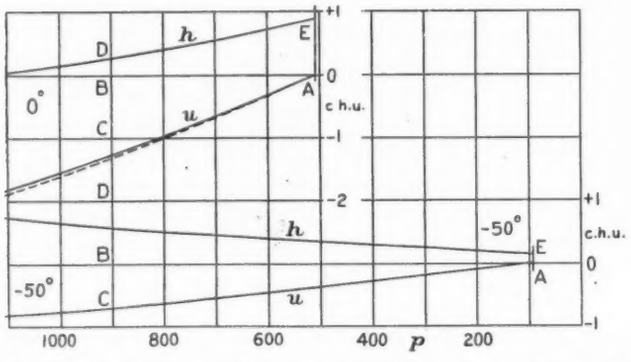


FIG. 12 VARIATION OF ENERGY AND ENTHALPY ALONG ISOTHERMS

will give a value of the required integral for Equation [8], here from saturation to $p = 1000$ lb. along the 5-deg. isotherm.

The effect of such a determination is shown by Fig. 10, at the 0-deg. isotherm. Entropy distance Δs or AB helps to locate the p-constant line PP from saturation line FF, in the T-s diagram. The shaded area beneath AB is the heat Δq that must be abstracted during compression in order to keep the temperature from rising. Understand that this heat area bears no direct relation to any area in Fig. 9; but the area equivalent to *CDGE* of Fig. 9 is shown by shading and corresponding letters in Fig. 11. Isentropic line AC in Fig. 10, by the height of point C where it cuts pressure line PP, gives the rise of temperature during an adiabatic compression.

A wide-range showing of the temperature-entropy dimensions of the liquid is made by Fig. 11, of which Fig. 10 is an enlarged detail: here the s-constant lines are inclined, in order to save space.

Consider now the variation of quantities u and h along the isotherm, as shown for the two temperatures 0 deg. and −50 deg. cent., by Fig. 12, with the pressure base turned horizontal and rising from right to left. The procedure for energy u, already indicated under Fig. 8, is as follows:

By successive values of Δs from Fig. 11 (measured from saturation to successive pressures) get $\Delta q = T\Delta s$;

From areas like *EABG* in Fig. 8 get corresponding values of the outer work $A\,\Delta w$;

By the subtraction $\Delta q - A\Delta w$ get energy decrease Δu.

In each case of Fig. 12 we start at point A with the saturation value of u and by line AC show the decrease of internal energy as pressure rises. Then the addition of Apv to give line ED shows the variation of total heat h. At −50 deg. the decrease of u is small and the increase of Apv overbalances it. At 0 deg. the shrinkage of u predominates and h also decreases.

In the relation or operation

$$\Delta u = \Delta q - A\Delta w \quad \ldots\ldots\ldots\ldots\ldots [11]$$

the outer work Δw is relatively small. Thus in Fig. 12 the quantities Δq and Δu are graphically indistinguishable at −50 deg. At 0 deg. the dotted-line curve shows Δq, and the full-line curve, Δu.

The h-variation so greatly magnified in Fig. 12 is brought to a true relative showing in Fig. 13, which is a complete h-on-p chart for CO_2. Besides the main set of isotherms (type *TT*, full-line) there are curves of constant entropy (type *SS*, dotted) and curves *QQ* of constant quality inside of the saturation boundary *FKG*.

Of the diagrams for CO_2 here laid out, Figs. 6 to 10 have been plotted or derived by the author from the data in Fig. 11 of the first Jenkin and Pye paper (Phil. Trans. Royal Society of London, Vol. A 113, 1913, p. 78). Fig. 13 of this paper is derived from the Mollier chart in the second Jenkin and Pye paper (Phil. Trans., Vol. A 115, 1915, p. 368).

CONDITIONS AS TO WATER

Not until the formulation of water is extended into the liquid region, in the manner suggested by Fig. 13 and including that portion of the Mollier chart, can questions of feed heating and the work of the feed pump be handled in a clear and definite manner, especially at high pressure. In the region of pressures below 200 lb. and feed temperatures below 200 deg. our old approximation has, however, been a good one. From the saturation p-t curve for H_2O, as here appended to Fig. 9, it is seen that the low-temperature isotherms are crowded very close together. As a consequence the entropy change Δs, like AB in Fig. 10, will be very small at 0 deg. cent.—if it does not even re-

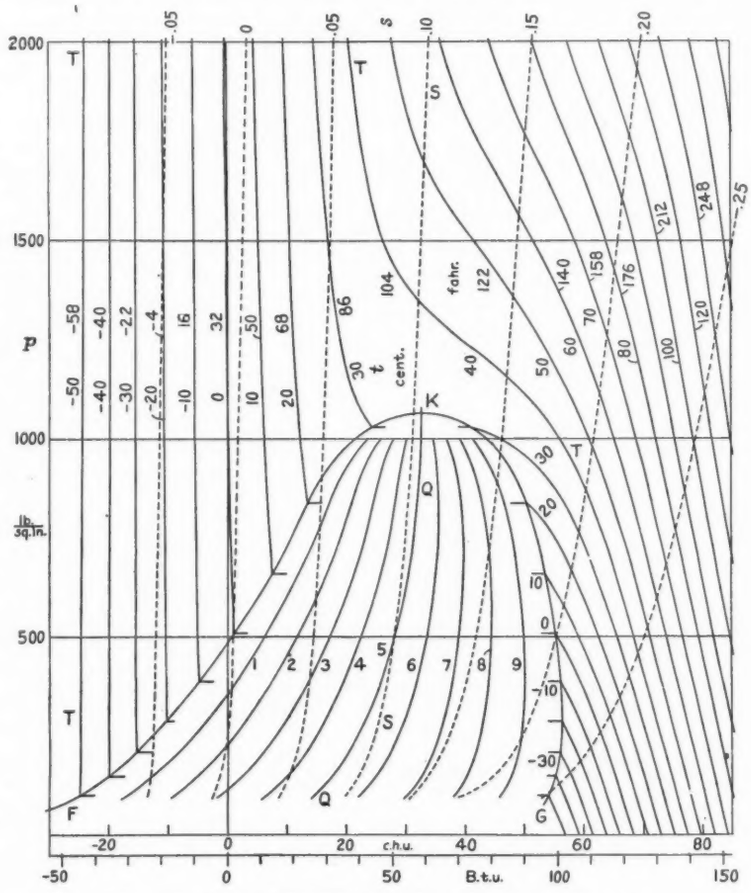


FIG. 13 THE PRESSURE-ENTHALPY DIAGRAM FOR CO_2

verse (in a very minute amount) because of the phenomenon of reexpansion of the liquid when cooled from 4 deg. to zero. Practically, this means that internal energy u_0 will be very nearly constant along the 0-deg. isotherm, instead of decreasing with rise of pressure as it does for CO_2 at -50 deg. in Fig. 12.

In review, the basic data for the liquid formulation are, first, complete volume measurements leading to a p-v chart like Fig. 8 or Fig. 9, and, second, a sure determination of the heat of liquid h_f, curve FK in Fig. 13. The Massachusetts Institute of Technology experiments will meet the first requirement to full range, while the Bureau of Standards will give h_f to perhaps 1200 lb. pressure. It would be well to extend and perhaps parallel that determination by enlarging our program to include the method used by Jenkin and Pye on CO_2.

This scheme is to heat the liquid under constant pressure, over a subsaturation range for that pressure, measuring heat imparting and calculating p-constant T-s lines like those in Fig. 10 or Fig. 11. Then by the application of Equation [8] the saturation curve would be derived from the p-constant curve or curves. The experiment would be by the flow method, essentially that used at Munich on superheated steam, with a pump and accumulator to maintain the high pressure and discharge through a flow-controlling throttle valve for measurement of the mass heated.

THE CRITICAL POINT

Incidentally, let us glance at the critical region in Fig. 13 and imagine one-degree isotherms interpolated between 30 and 40 deg. Consideration of their necessary shape and spacing will indicate strongly the futility of trying to use heat measurements in that region to determine the shape of the saturation "dome" and even whether it exists—such measurements being, for steam at least, not of the highest probable precision. Under quiet and static conditions, with plenty of time for coming to equilibrium, this upper part of the saturation boundary may be fairly definite. In any kind of kinetic action, as in a throttling experiment, it seems likely to be very vague.

[C. Harold Berry,[2] at the conclusion of Professor Heck's discussion, said that he was much interested in the constant-pressure lines the latter had drawn for unsaturated liquid. It might be of interest, he stated, to note that Prof. J. E. Trevor, of Cornell University, had plotted such lines in the region below the maximum density boundary for water. They presented a curious array. Incidentally, in that region it was possible to have sixteen distinct Carnot cycles with the same two isotherms and the same two isentropics. Professor Trevor's discussion of this situation appeared in the *Sibley Journal of Engineering* for November, 1928, page 274.]

The Passing of the Mechanical Equivalent of Heat[1]

BY E. F. MUELLER,[2] WASHINGTON, D. C.

THE discovery and experimental demonstration during the 19th century of the fact that a definite quantity of mechanical energy is convertible into a definite quantity of heat, has justly been recognized as one of the outstanding developments of that period. The discovery is closely associated with the generalization expressed in the principle of the conservation of energy and the special form in which that principle is stated in the first law of thermodynamics.

The expression "the mechanical equivalent of heat" appears to be used with two distinct meanings. The first and fundamental one is that heat and work are quantities of the same kind, and that a definite amount of one is equivalent to a corresponding amount of the other. This equivalence of heat and work is one of the most fundamental principles of physics.

The "mechanical equivalent of heat" is much more commonly used, however, in textbooks and elsewhere to denote the relation between the arbitrary units in which heat and work, respectively, are ordinarily measured. Thus "heat" is regarded as something to be measured and expressed in terms of the heat capacity of water; that is, heat is measured in calories or B.t.u. "Work," on the other hand, is something measured in mechanical units, and a determination of the mechanical equivalent of heat gives the relation between these two independent units of energy. The precise determination of the numerical conversion factor was considered to be of great importance, as is attested by the list of famous names, including those of Joule and Rowland, connected with it. Every important paper devoted to the subject, including reviews of experimental data, conveys the idea that this conversion factor, usually called the "mechanical equivalent of heat," is an important physical constant.

Such ideas were perhaps justified when the only practicable methods of measuring heat were those based on the heat capacity of water, and when the simplification resulting from measuring all quantities of energy in terms of a single unit so that no conversion factor would be needed, and no mechanical equivalent of heat would occur in the equations of thermodynamics, represented merely an interesting theoretical possibility. The idea of a single energy unit is of course not new, being at least as old as the c.g.s. system of units, in which the only unit of energy is the erg.

INCREASING USE OF JOULE AS BASIC LABORATORY UNIT OF HEAT

More recently, and particularly during the last thirty years, the availability of precise methods of measuring power electrically has led to the increasing use of the joule or watt-second as the basic laboratory unit of heat. In many experiments a quantity of heat, measured in joules, was added to a calorimetric system, and the resulting effects, such as temperature rise, quantity of material evaporated, etc., were determined. In other cases the heat capacity of a calorimetric system was determined in joules per degree, and when such a system was then used to measure thermal quantities, such as latent heats, or heats of reaction, the result was given directly in joules. But while for many years experimental results have been obtained in terms of joules, acceptance of the joule as a basic heat unit has been hampered by habit and tradition. In the transition period, data originally obtained in joules were, before publication, converted into calories, in some cases by ingenious methods which made it impossible to determine what conversion factor had been used, and in others by use of a definite conversion factor.

During the last few years there has been a decided drift away from the idea that quantities of heat can be measured and ex-

[1] Publication approved by the Director of the Bureau of Standards of the U. S. Department of Commerce.

[2] Physicist, Bureau of Standards.

For presentation at the session on Steam Tables Research at the Annual Meeting, New York, N. Y., December 2 to 6, 1929, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

NOTE: Statements and opinions advanced in papers are to be understood as individual expressions of their authors, and not those of the Society.

[2] Professor of Mechanical Engineering, Harvard Engineering School, Cambridge, Mass. Mem. A.S.M.E.

pressed only in calories or B.t.u. In the greater part of "International Critical Tables," for example, the joule is used as the heat unit. But it is evident that when all energy quantities are expressed in terms of a single unit, the necessity for a conversion factor between two independently defined units ceases to exist.

DISCARDING THE CALORIE

One of the important acts of the International Steam Table Conference, held in London in July of this year, was its move to discontinue the further use of two independent energy units. The conference recommended that the international kilo-calorie be defined as the equivalent of $^1/_{860}$ international kilowatt-hour. Where this recommendation is followed the calorie loses its existence as an independent unit, and with it pass most of the difficulties and misunderstandings associated with the 0-deg. calorie, the 4-deg. calorie, the 15-deg. calorie, the 18-deg. calorie, the 20-deg. calorie, the orthobaric and isopiestic mean calories, and their several mechanical equivalents.

In discarding the second independent unit of energy, practice in this field recognizes what has already been learned elsewhere, notably in connection with electric units: that independently defined units, the relation between which is to be determined experimentally, can reach a stable condition only when experimental work already completed is more accurate and reliable than any which may be done later. The recommendation of the London Conference that only one basic unit of energy be used means that the mechanical equivalent of heat, as an experimental relation between two independent units of energy, is no more. This discussion is presented to celebrate the passing of this conception of the mechanical equivalent of heat. The Steam Table Conference is to be congratulated that one of its major problems, the mechanical equivalent of heat, has been disposed of with a degree of finality that was doubtless not anticipated when its program was formulated.

It is not at all certain that the numerical value adopted at London will be retained permanently, because it is based upon the International watt-second, which is known to differ by about 1 part in 3000 from the absolute watt-second, and it is not at all improbable that the present International electric units will be superseded within the next five or, perhaps, ten years by absolute units. When this change is made, it may or may not prove desirable to change the number now used to define the calorie.

The International Conference made no recommendation as to the definition of the B.t.u., this being a local question. It is obvious, however, that to realize the advantages of the forward step taken by the International Conference, it will be necessary, where the B.t.u. is retained, to define it also as an energy unit, and not in terms of the properties of water. Since any calorie, say, the mean calorie, is related to the corresponding B.t.u. by the equation

$$1 \text{ B.t.u.} = \frac{453.59}{1.8} \text{ calories} = 252.00 \text{ calories}$$

it would appear appropriate to use this same relation which involves only the relative sizes of the pound and kilogram and of the fahrenheit and centigrade degrees, to define the B.t.u. corresponding to the International calorie. The derived B.t.u. so defined is equal to 778.3 ft-lb. If the calorie were defined as $^1/_{860}$ absolute watt-hour, the corresponding B.t.u. would be equivalent to 778.0 ft-lb. It is entirely probable that we shall, for our own inconvenience, continue to use two units of energy in connection with steam tables. In that case it might be preferable to use a definition of the calorie which would make the B.t.u. an (nearly) integral number of foot-pounds rather than one which would make the change in enthalpy of water between its freezing and boiling points equal to 180 B.t.u., or which would make the heat capacity of water at some selected temperature exactly equal to 1 B.t.u. per pound-degree. From this point of view, those who use the B.t.u. would prefer, when the change from the present International to absolute units is made, to retain the number 860 and change the size of the calorie, rather than to change the number and keep the size of the unit unchanged.

WILL FURTHER MEASUREMENTS OF THE MECHANICAL EQUIVALENT OF HEAT BE MADE?

Since the value of the "mechanical equivalent of heat" is to be fixed by definition, what becomes of the numerous careful and elaborate determinations of this equivalent, and what is the probability that further measurements of this kind will be made? The experiments now on record become a contribution to our knowledge of the heat capacity of water, and since its heat capacity is no longer employed in the definition of a primary unit of energy, it seems possible that the data we now have will be adequate for an indefinite period. At any rate, measurements of the specific heat of water will no longer be considered as involving a determination of the mechanical equivalent of heat, but will have the same status as measurements of the specific heat of any other material. But since energy can be measured in such a variety of ways, both electrically and mechanically, it may be worth while, at some future time, to conduct careful experiments in which quantities of energy, measured, for example, electrically and mechanically, are compared by means of the thermal effects produced. Experiments of this type seem to be best adapted to answering the question whether, within the limits of experimental accuracy, the electrical and mechanical methods of measuring energy are directly comparable and consistent with one another.

It is of interest to consider whether the action of the London conference leaves our heat and energy units in a stable condition, or whether it is merely one of a series of steps to make these units more suitable for their purpose. The fact that the conference defined the calorie as a rather awkward fraction of a more fundamental energy unit suggests that the action is an expedient designed to meet the present situation. We may anticipate that the calorie and B.t.u., being no longer fundamental units but being derived from fundamental units by means of somewhat inconvenient factors, will tend to fall into disuse. In other words, the tendency will be to express quantities of energy in terms of our fundamental units of energy and not in terms of an inconvenient multiple or fraction of such units. But if it becomes customary to express all quantities of energy in the same units, there will no longer be occasion for using two energy units with one steam table, and we shall doubtless have steam tables requiring only one unit of energy. Although the second law of thermodynamics requires a careful discrimination between energy in the form of heat and energy in other forms, this does not mean that the distinction can be made clearer by the use of two units of energy, or that it is necessary to choose units which will introduce a mechanical equivalent of heat into the equations of thermodynamics.

NATURAL ENERGY UNIT FOR STEAM TABLES

The natural energy unit for a steam table is one equal to the product of unit pressure by unit volume. If pressures were expressed in pounds per square foot, and volumes in cubic feet, the unit of energy would be the foot-pound. It is not at all probable that a table of this kind will ever be used.

In the metric engineering system the use of a single unit of energy for a steam table seems entirely feasible. It must first be recognized that the system, as used at present, can

claim no special superiority over the British system, because it contains two units, the kilo-calorie as a unit of energy and the kilogram weight as a unit of force, which are extraneous to the metric system proper, and necessarily introduce awkward conversion factors. By retaining the kilogram as the unit of mass, the meter as the unit of length, but defining the unit of pressure as the megabar or atmosphere equal to 10^6 dynes per sq. cm. (a change of about 2 per cent from the present unit), the product of unit pressure by unit volume would be equal to 10^{12} ergs, or 100 kilowatt-seconds. This unit of 100 kilowatt-seconds is an energy unit of fairly convenient size, being equal to about 24 kilo-calories or 95 B.t.u. It is simply related to the laboratory unit of heat, being equal to 10^5 joules, and is as simply related to the kilowatt-hour as our system of measuring time permits. All energy quantities of interest in a steam power plant, from the heat of combustion of a kilogram of fuel to the output of the generator, could be expressed in this one unit. In a hydraulic plant it would be found that a cubic meter of water falling through a distance of 10.2 meters, or for purposes of mental arithmetic through 10 meters, would be capable of generating 100 kilowatt-seconds, or one unit of energy. In such a system there would be no occasion to use the conversion factor adopted at London.

The system suggested has its drawbacks, of course; the principal one being that the units do not, together with the second, form a normal system, so that, for example, the unit of force, acting on unit mass, would not produce unit acceleration. In particular, the kinetic energy in a jet of steam, expressed as $^1/_2\ mv^2$, will not be in the same units as the heat drop from which the kinetic energy was derived. One of the units in which the two are expressed is 10^5 times as large as the other. Probably no one would wish to call this conversion factor a mechanical equivalent of heat, although it is a ratio of the same kind as the ones commonly bearing this title.

While we are doubtless very far from being ready to use a table of the kind outlined, it is of interest as representing a possible outcome of what was started at the London conference. For in accepting the principle that the purpose of our units is not primarily to maintain the best traditions of the past but to serve our present needs, the conference has opened a way which we may follow either to a logical conclusion or as far as best serves our purposes.

The Agreement on Steam Tables

THE International Steam Tables Conference which was held in London last July has not been long in justifying the hopes of its promoters. How they set about their task and the results so far achieved are shown in the report of the Conference.

The idea of tabulating the properties of steam with a tolerance to allow for errors is a new one, but it is none the less appropriate to figures which, in the nature of things, can hardly be relied on to more than a certain number of decimal places. In existing steam tables, although no tolerance is stated, every engineer knows that absolute accuracy is unlikely. The new tables are thus more explicit than the old ones, for in place of the doubt as to the degree of faith that may be placed in any given figure, the reader is provided with limits between which the truth must certainly lie.

The production of the first international steam table, even in its present elementary form, raises acutely the question of the units in which the properties of steam shall be expressed. In all the English-speaking countries, the fahrenheit scale of temperature still enjoys popular favor, though for scientific work it has long been discarded for the centigrade scale. For calculations relating to steam the intolerable nuisance of a zero of temperature thirty-two degrees below the zero from which total heat and entropy are reckoned has induced very many engineers to abandon the fahrenheit scale, and in standard works like Ewing's "Thermodynamics for Engineers," and Callendar's "Properties of Steam," the centigrade scale is used exclusively. If the agreement on an international steam table leads to the agreement of all engineers to adopt an international way of expressing temperatures, much good will be done. But even so, this would only be a step toward that full comprehension of each other's units which is enjoyed by those engaged in electrical or chemical work in different countries. When it comes to matters of pure calculation, amenable to logarithmic and slide-rule processes, a decimal division of units is highly convenient. Steam calculations fall into this class, and were metric units as familiar to all British steam engineers as the foot-pound units, there can be no question that they would be employed in computations, with the added advantage that the figures of one country would be intelligible in another. The unit of heat employed by continental engineers is the kilogram-calorie, defined as one-hundredth of the quantity of heat required to raise the temperature of a kilogram of water from the freezing to the boiling point at atmospheric pressure. The desire to get away from the awkwardness of the fahrenheit scale of temperature, while retaining the familiar British unit of mass, has resulted in the introduction of a cross-bred unit of heat—the pound-calorie—which is now largely used. Its equivalent in foot-pounds is 1400 exactly, a more convenient figure than the 778 ft-lb. corresponding to the B.t.u. The very fact, however, that a heat unit must be expressible in work units involves the use of a conversion factor, such as Joule's equivalent, and any correction of this factor resulting from increasing knowledge upsets the relationship established. Engineers not much past middle age will remember when 772 was taken as the value of Joule's equivalent. Then it was increased to the generally accepted figure of 778, until less than two years ago, when the American Bureau of Standards decided that 778.6 was a still more accurate value. But since heat is equivalent to work, it can be expressed in electrical as well as in mechanical units of work. Watt-seconds and kilowatt-hours have internationally accepted values, and by defining the heat unit in terms of the kilowatt-hour, the Conference has put it on the international footing so urgently required. Objections might be raised to the actual expression of heat quantities as fractions or multiples of a kilowatt-hour, on the ground that such a nomenclature might be taken to imply the possibility of the complete conversion of heat into useful work. This difficulty has been overcome by the retention of the name "kilo-calorie" as a unit of heat, but defining it as the heat equivalent of $^1/_{860}$ kw-hr. The choice of this divisor was dictated by the desire to give the new heat unit as nearly as possible the same value as the existing kilo-calorie. It is much the same thing as if British engineers were to decide to alter the definition of the B.t.u. to $^1/_{3412}$ kw-hr., to which it is almost exactly equivalent. The new definition of the kilo-calorie marks a distinct step toward the rationalization of units, and the Conference is to be congratulated on its decision. As regards the various conversion factors it has adopted, the only comment one can make is a regret that they are still necessary.—From editorial comment in *The Engineer* (London), Dec. 6, 1929, p. 609.

The Economic Status of Engineers in the Federal Service[1]

Report of a Committee Pointing Out the Advantages and Disadvantages Which the Federal Service Has for Engineers—Conditions Which Should Be Remedied in Order to Improve the Efficiency of the Service Rendered and Economize Public Funds

IN PREPARING this report the primary purpose of the Committee was to assemble information relating to conditions under which engineers in the Federal service work. In presenting some conditions it is not possible to isolate the engineer, as the situation may be of such a broad general character as to include many other classes of Government workers. Such instances as may be apparent in this report are presented as indicating the viewpoint of the engineer and without selfish motives or prejudices with respect to the working conditions of employees of other callings or professions affected by the condition under discussion.

More and more attention is being paid of recent years to the efficiency of the Government. This public interest is due in part to the larger proportion of the individual income which is taken as taxes since the World War, and in part to the greater dependence of the individual for health, success, and happiness upon the activities of the Government. Our forefathers depended for little upon the Government, except protection from foreign enemies and the transportation of mail.

The engineer in the Federal service is as interested as the taxpayer at large in the efficiency of the service, perhaps more so because the conditions under which he works, either good or bad, affect him and his individual contribution to Government efficiency more directly than they do the taxpayer.

In presenting this report, the Local Committee offers it to the General Committee for comparison with information on engineers in industrial and commercial work. Some conditions discussed may appear to affect but few engineers. They will, in all probability, be cleared up in a reasonable time, but they are included here so that the General Committee may have a complete picture of the present situation.

ADVANTAGES WHICH THE FEDERAL SERVICE HAS FOR ENGINEERS

The advantages which the Federal service has for engineers are set forth by United States Civil Service in its booklet "Opportunities for Engineers in the United States Civil Service."[2] Among these are: Exceptional opportunities for the acquisition of diversified engineering experience, some positions offering a wider variety than can be gained in much longer periods in private industry; equally good opportunities for engineers who prefer to specialize in certain branches; the opportunity to pursue postgraduate college work in evening classes at Washington educational institutions; contacts with men of national and even international reputation; 30 days annual leave; sick leave; retirement with annuity; better prospects of steady work than in private employment; etc. Many government engineers command a better salary upon entering private industry due to experience which they have had in the Government service.

The Committee believes that the Civil Service booklet gives a fairly accurate picture if it is agreed that many branches of the service give young engineers an excellent training and opportunities for advanced study which cannot be found elsewhere. Due consideration, however, must be given to the fact that the entire publication is "sales literature," and apparently emphasizes the exception rather than the rule. It also appears that special emphasis is placed upon the demand from private industry for engineers who have been successful in their Government work. Apparently it is accepted as a fact that the ambitious engineer cannot expect to remain satisfied within the Federal service.

Throughout the Civil Service booklet the impression is conveyed that Federal service and training have an intangible value which is offered in lieu of substantial and just remuneration, but in order to realize any return from this intangible compensation it is necessary for the employee to leave the Federal service. As the primary element concerning the economic status of the engineer is that of compensation, it is the opinion of the Committee that an unsound and incorrect principle is being applied when the Government pays part in cash and part in "opportunity to obtain a job elsewhere." The economics of this policy are unsound from the Government standpoint alone, as the heavy turnover among engineers in Federal service is an economic waste which could be avoided by making it an object for ambitious talent and ability to remain in the service of the Government.

ADVANTAGES FOR NON-COMPETITIVE ENGINEERS

Everything which has been presented so far deals with the advantages which can be weighed or measured, at least approximately. The assumption has apparently been made that the conditions under which engineering work is carried out are practically the same in private industry as they are in the Federal service. The discussions which appear from time to time in the more thoughtful periodicals as to the advantages and disadvantages of "Big Business" as a career for college graduates indicate clearly that the men who are successful in these organizations submit to restrictions which do not hamper the man who heads his own small enterprise. In the big organization it is necessary to march in "lock-step," so to speak.

In the opinion of the Committee these conditions do not exist in the non-military branches of the Federal service. There is a surprisingly sympathetic and cooperative attitude toward those under their direction on the part of those in charge of the work. This is particularly true of technical and scientific work, especially research.

In the Federal service, in the first place, the standard for work is neither how cheaply nor how quickly but how well can the work be done.

In the second place, there is a spirit of helpful cooperation

[1] Report submitted August 20, 1929, by the Washington, D. C., Section of the A.S.M.E., and published here in greatly abridged form. The Committee charged with preparing the report was appointed by A. E. Hansen, Chairman of the Section, and began its activities in November, 1928.

[2] "Opportunities for Engineers in the United States Civil Service," Form 2599, November, 1926, United States Civil Service Commission, Washington, D. C.

among engineers on a Government enterprise which is often lacking on a commercial job.

In the third place, many lines of work, especially research, are encouraged and supported by the Government which receive little or no support from industry.

In the fourth place, in Federal service too much emphasis is not placed upon a failure, particularly if the work is difficult or has never been done before. The reverse is true in many commercial organizations.

It is evident that the Federal service provides for many persons who are square pegs in round holes in commercial organizations because they either have no desire to or actually cannot bend their entire energy to commercial gain. We should not lose sight of the fact that many of these square pegs in the past have revolutionized our science and industry.

DISADVANTAGES OF THE FEDERAL SERVICE

The consensus of opinion in this country is that civilian appointments in the Federal service, presumably under the U. S. Civil Service, are much less desirable than the other opportunities open to the same person. This applies particularly to the clerical, custodial, and other non-professional activities. To a less degree it applies to professional positions, such as engineering.

It is said that the engineering schools of this country advise their graduates against accepting Government positions.

The following opinion written for the Committee by a civilian engineer in the Navy Department points out some advantages of the Federal service for engineers, but apparently the disadvantages outweigh the advantages.

> As regards the advantages and disadvantages of governmental work for young men with technical training, my experience of between seven and eight years with the Navy leads me to believe that the young engineer has unusually favorable opportunities for the development of initiative in minor things on account of the large variety of work which is set before him. On the other hand, unless he is of an unusual type, he is very apt to become "bureaucratized" from the fact that he has very little responsibility for results, no competition, since he is under Civil Service, and with no incentive to push himself since promotion is a matter of years of service and pull rather than of productive ability, and is slow and uncertain at best. The whole atmosphere of Government technical service tends to a gradual lessening of ambition, because the ordinary stimuli tending to keep the young engineer "on his toes" are lacking, as he has practically no opportunity to attend professional meetings and is substantially forbidden to discuss or prepare professional papers except after the unwinding of an interminable amount of red tape. His superiors in many cases have less technical training, experience, and ability than has he, a fact which he very quickly recognizes, and they have no incentive to stimulate him to advance in a profession.

"AVERAGE OF THE GRADE" RESTRICTION

Section 6 of "The Classification Act of 1923" provides that:

> All new appointments shall be made at the minimum rate of the appropriate grade or class thereof.

Section 7 provides in part that:

> Increases in compensation shall be allowed upon the attainment and maintenance of the appropriate efficiency ratings, to the next higher rate within the salary range of the grade. . . .

These provisions seem fair enough on their face, but the provisions of Section 7 are largely annulled by the "average of the grade" proviso injected into the appropriation bills. This results in many engineers' being "frozen" at the minimum of their respective grades where the average has been reached or is exceeded, as is the case in instances where other employees were receiving the maximum of the grade when the Classification Act became effective. In this manner one law grants wage increases and another law snatches them away.

EFFICIENCY RATINGS

Efficiency-rating procedure was planned to prevent injustices and discriminations, but many engineers in the Federal service believe that, in practice, it is often used for the purpose of rewarding friends. When so used it effectually prevents others whose work would merit higher compensation from receiving deserved recognition. In the hands of an unscrupulous administrative officer a person could be dismissed from service if the officer continually rated the employee lower and lower until the minimum allowable rating was attained. In a case of this kind the employee would have no redress and could not obtain a hearing as granted by the Civil Service Law in case of other dismissals.

CLASS SPECIFICATIONS

Where large numbers of persons are employed in one institution it is a distinct advantage for both employer and employee to have the duties and qualifications of each employee clearly defined, and the "class specifications" therefore, theoretically, serve a useful purpose. If the system were followed conscientiously, and the duties of each employee as specified on the "job sheet" which is made out by employing officers and corresponds closely with the "class specification" for the range of salary in which it is intended to place the employee, were actually performed by the employee, there could be little or no legitimate objection to the system.

The experience of some engineers in the service convinces them that actually it is all too common for administrative officers to "pad" the job sheets of favorites, thus placing them in higher grades than the actual work performed would warrant, and to minimize the duties on job sheets for others who are less favored, thus depriving them of the class specification and salary justly due. However, the Personnel Classification Board is powerless to prevent underclassification, because an employee cannot appeal his rating except through his administrative officer—the same officer who is responsible for the underclassification.

PREREQUISITES

Recent announcements of examinations to be held by the United States Civil Service Commission are of great interest as they give the title and salary for each position, followed by the duties or work to be performed and the prerequisites or training and experience which is required.

These "minimum qualifications" are probably as they should be in order to insure a high-grade personnel, but where high educational qualifications coupled with "extended experience, outstanding professional attainments, and proved executive ability of a high order" are required for a salary not materially greater than the earnings of a person who has served an apprenticeship at a mechanical trade, it cannot be said that the engineer has received proper recognition in the matter of compensation.

HOURS OF DUTY

Contrary to the usual impression, the hours of duty in the Federal service are not materially different from those in industry. While there are some exceptions, it may be said in general that the hours of duty in the Federal service are 7 hours a day for six days in the week, including Saturday, making a total of 42 hours of duty per week except for the summer months from June through September, during which time 4 hours' duty constitute a day's work on Saturday, making a total of 39 hours' duty per week for the summer months.

MILITARY SERVICES

It is surprising that military departments of the Government employ a large number of civilian engineers in technical and

scientific positions. Some non-military departments employ engineers in the highest positions, such as chiefs and assistant chiefs of bureaus. In the military departments, these positions are always occupied by commissioned officers.

Relations between commissioned officers and civilian engineers have changed materially since the outbreak of the World War, resulting from a broadened outlook on the part of both groups.

On the whole, the engineer in the military services would appear to be at no disadvantage with reference to salary as compared with other branches of Federal service, except as to opportunity for promotion to the grades of assistant chief or chief of a bureau. With reference to training for positions in civil life, some of the work is of a highly specialized application found only in the military service; however, much of it is of more general application and comparable to regular engineering work.

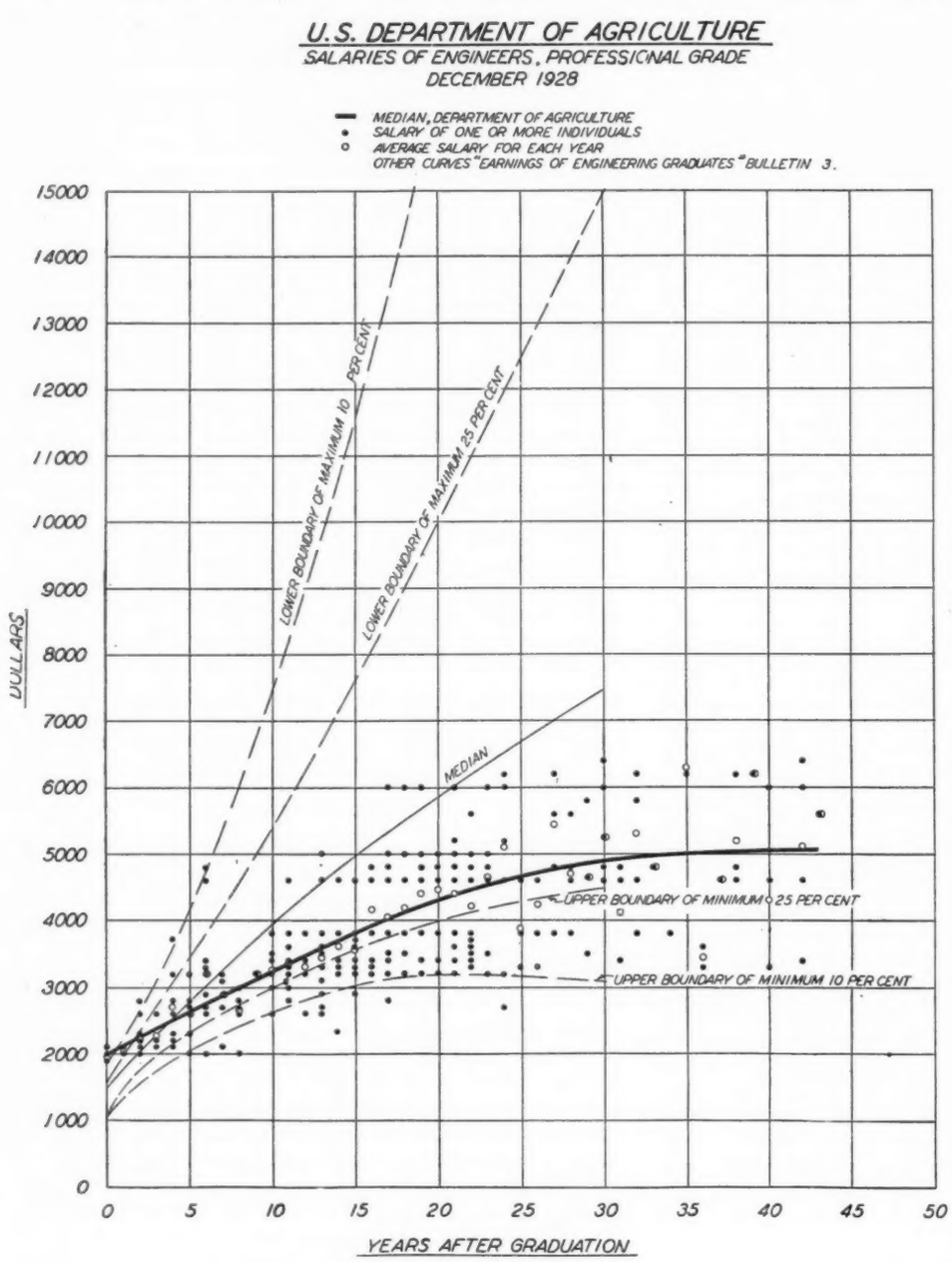


FIG. 1

RETIREMENT

Under the terms of an Act which became effective August 20, 1920, disabled and retired civil employees are paid annuities in varying amounts depending upon age, length of service, and salary, but in no event more than $1000 per annum. Annuities are paid from the "civil-service retirement and disability fund" which is maintained by contributions from the Government and the employees. From each civil employee's "basic salary, pay, or compensation" there is withheld "a sum equal to 3½ per centum of such employee's basic salary, pay, or compensation" to be deposited in the Treasury of the United States to the credit of the above retirement fund. In the event of an employee's resignation or death the total amount deducted from wages is returnable to the employee or his estate with interest at 4 per cent.

A comparison of Government practice with that in the railroad industry shows the injustice and the inadequacy of the present retirement laws.

PAY

One hears on all sides that the pay in the Federal service is much lower than for similar work in private industry. All the other disadvantages of the service shrink almost into insignificance compared to the question of pay. If the engineers working for the Government felt that they were fairly and adequately paid, they would continue in the service with enthusiasm and public opinion would change very quickly.

The Committee has considered carefully the proper basis for paying Federal engineers, and believes that to secure competent service the Government must pay salaries at least equal to the average paid by private industry for similar work. This is necessary because the Government competes with industry for engineering service, and because in many instances industry looks to the Government engineers for guidance and assistance in major problems.

The Government cannot afford to pay less, in the belief that the pleasant surroundings and congenial work will attract and hold competent technical men. These advantages are insignificant when compared with the large salaries and other financial rewards which some engineers gain in commercial work.

It must be remembered, too, that a Federal engineer is very

likely to be looked upon by his colleagues in industry with a mixture of contempt and pity because he is not using his ability to better advantage. This attitude colors somewhat all the relations between Federal engineers and industry, and conditions will have to improve a great deal to change this public opinion.

The Committee believes that if the pay of Federal engineers were above the average outside, the efficiency would be increased in a greater ratio.

After considerable study the Committee selected as best representing industrial salaries the bulletin, "A Study of Engineering Graduates and Non-Graduate Former Students."[3]

Fig. 3 on page 7 of this bulletin may be considered a summary of the data on earnings. This graph has been widely used when discussing the earnings of engineers, so that in all probability it is the best yardstick by which to measure the salaries of engineers in the Federal service.

Therefore, when plotting the salaries of Federal employees in Figs. 1 and 5, the curves from the above-mentioned graph were also plotted. It should be remembered that the curves shown by light lines, "lower boundary of maximum 10 per cent," "lower boundary of maximum 25 per cent," "median," "upper boundary of minimum 25 per cent," and "upper boundary of minimum 10 per cent," do not apply to the Federal service. The curve shown as a heavy line represents salaries in the Federal service.

An attempt was made by the committee to obtain data on the salaries of engineers in the Federal service from the Civil Service Commission. It was soon found, however, that this was out of the question because of the large number of personnel cards which would have to be examined to determine whether or not the person was in fact an engineer.

Several Government Departments employing mechanical engineers were then selected and the necessary information obtained from the Personnel Officer.

Complete information could not be obtained without the services of paid investigators. It is believed that these graphs for five departments (Figs. 1–5) give a reasonably accurate picture of conditions in the Federal service, especially as the Personnel Classification Board approves every appointment and change in grade. This Board makes a great effort to see that the employees' qualifications, grade, and work are uniform throughout the Federal service.

A very complete discussion of the salaries received by the faculties of colleges and universities compared with similar positions elsewhere has recently been published in *Science*.[4]

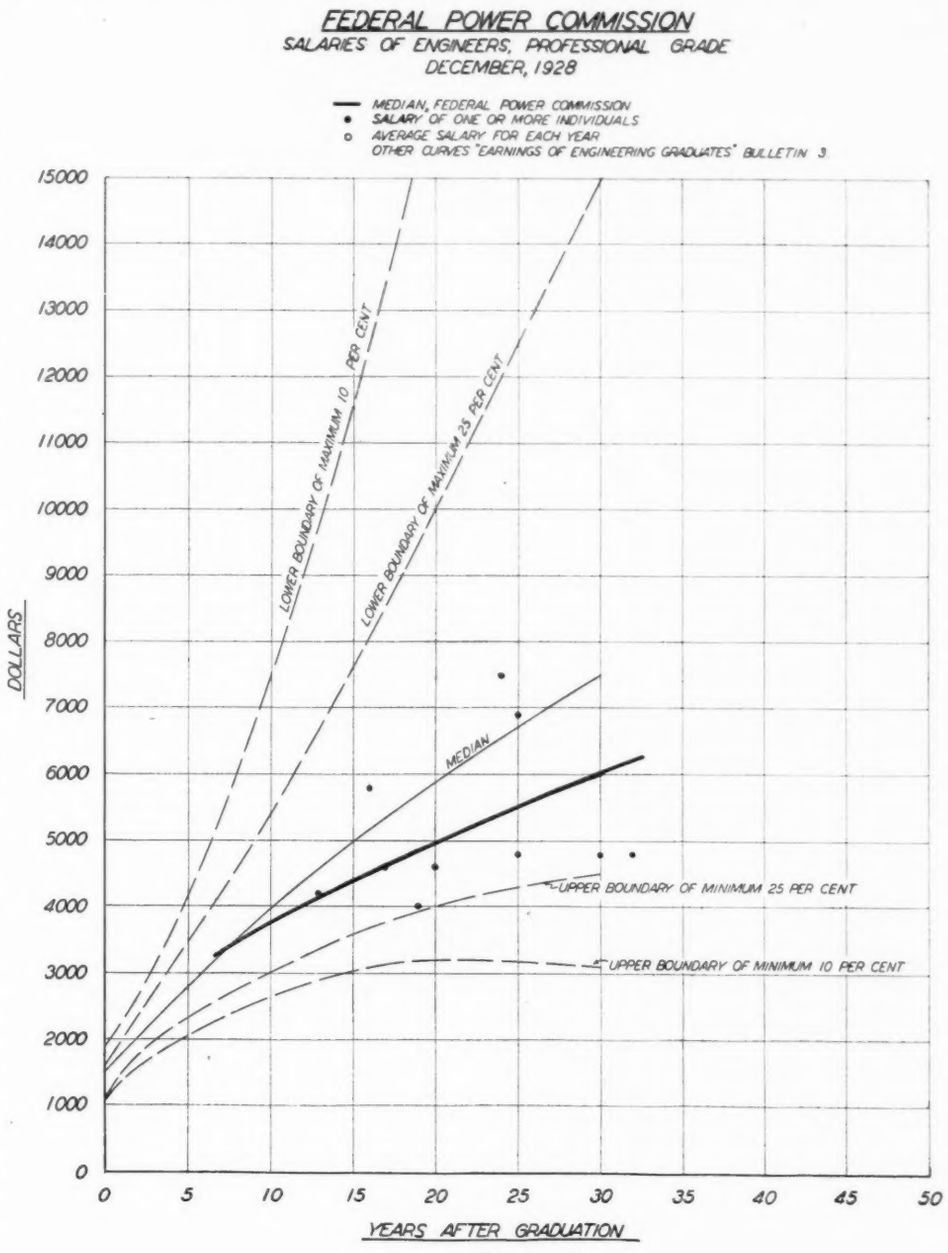


FIG. 2

The salaries paid by the United States Government in the Civil Service and in the Army and Navy are discussed by Professor True. He compares the salaries paid by colleges and the Government with those paid by business enterprises. He was very fortunate in obtaining sufficient data on commercial salaries

[3] Bulletin No. 3 of the Investigation of Engineering Education of the Society for the Promotion of Engineering Education, October, 1926. Published by the Lancaster Press, Inc., Lancaster, Pa.

[4] "The Economic Status of Scientific Men and Women." Part 1: Budget Needs of College Teachers, by Dr. Benjamin R. Andrews; Salaries and Supplementary Earnings of College Teachers, by Frank P. Bachman; and Part II: Salary Scales of Trained Men and Women, by Prof. Rodney H. True. *Science*, July 12, and 19, 1929, vol. lxx, no. 1802, pp. 19 and 26, and no. 1803, p. 47.

to allow a comparison to be made with college and Government salaries.

Professor True's conclusions, which confirm the conclusions drawn by the Committee from salary charts, Figs. 1 to 5, are as follows:

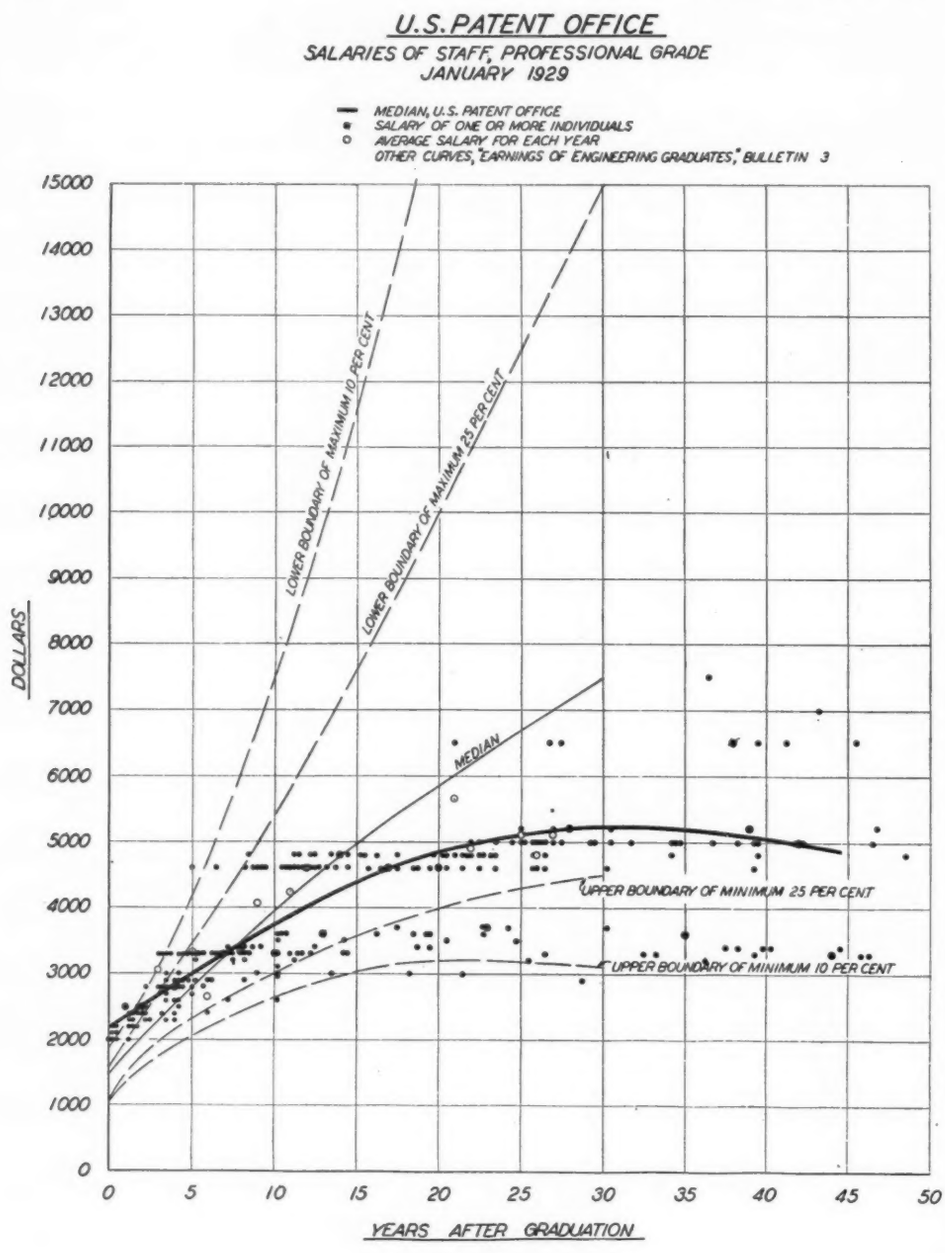


FIG. 3

A comparison of salary scales shows rather clearly that:

1 The pay scale of endowed and state universities and agricultural colleges is approximately like that of the commissioned officers of the Army and the Navy, but lacks the advantage of the retiring pension of three-fourths pay. This pension often relieves the military and naval officer of the necessity of saving for old age. The saving required of the academic man to give him an equivalent retiring fund is not practicable at the present salary scale.

2 It shows that the academic salary scale is appreciably lower than that of the professional and scientific services of the National Government at Washington. The retiring allowance of the Government employee, though small, and in part contributed by the employee himself, gives him a distinct advantage.

3 The salaries of all groups above mentioned are very much lower than those paid in manufacturing enterprises to positions above the wage earners.

GRADING OF ENGINEERS

At present the pay of engineers in the Federal Service is fixed by the Act of May 28, 1928, popularly known as the Welch Bill. Eight grades are provided for, the annual rates of compensation having, respectively, the following ranges: $2000–$2500; $2600–$3100; $3200–$3700; $3800–$4400; $4600–$5200; $5600–$6400; $6500–$7500; $8000–$9000.

Considering only the bureaus having a considerable number of engineers, it is noted[5] that the Forest Service and Bureau of Public Roads are, so far as can be judged, stable organizations, as indicated by the large proportion of engineers in grades 3 and 5. Apparently the number in grades 1 and 2 is not excessive compared with the number of men of more mature experience and judgment.

In the Bureau of Lighthouses the comparatively large number of engineers in grades 2 and 6 shows a lack of balance in the organization unless the conditions are very unusual. The Bureau of Mines appears more normal. The Patent Office shows that most of the work is done by men in grades 1 and 2, which are, practically, apprenticeship grades for training men for more responsible positions. It seems likely that when industry awakens to the fact that very few men stay in the Patent Office longer than is necessary for them to graduate, in evening classes, from one of the law schools of Washington, conditions will be made more attractive.

In the Bureau of Standards the number of engineers in grades 1 and 2 appears large, but it must be remembered that in this bureau engineers are working with physicists and others.

The work of the Supervising Architect's Office appears to be directed by men of experience, as a fair proportion are shown in grades 4, 5, and 6.

Apparently the National Advisory Committee for Aeronautics has a comparatively large number of inexperienced men in grades 1 and 2, and very few in the higher grades.

The Interstate Commerce Commission appears to be fairly

[5] "Opportunities for Engineers in the United States Civil Service," Form 2599, October, 1928. (This is a later edition than the one referred to previously.)

well balanced except for the large number of engineers in grade 2.

The War and Navy Departments appear to be fairly well balanced except in the Quartermaster Corps, where a large number of men in grades 2 and 3 are found. This may be due to the fact that commissioned officers are not included, although they take the place of civilians who might otherwise occupy the higher grades.

These salary charts show that the pay of engineers in the Federal service is remarkably uniform for all departments, as was to be expected, and that the average pay is but little above the upper boundary of the minimum 25 per cent for all engineering graduates. For the first few years the average pay in the Federal service is appreciably higher than the average pay of all engineers. For 20 years or more after graduation the average pay in the Federal service is very appreciably less than the average pay of all engineers.

The averages for the five branches of the service given here are: 10 years after graduation, $640 per year below the median for all engineering graduates; 20 years after graduation, $1220 below; and 30 years after graduation, $2040 below the median.

The Federal engineer by these circumstances is placed in a false, unsatisfactory, and unenviable position. The Committee wishes to emphasize its conviction that under present conditions the Government can neither expect to attract nor retain for the Federal service young engineers entering the profession or older men with years of experience. These conditions might lead one to think that only engineers of less than average ability seek appointment or remain in the Federal service, whereas Government engineers by reason of ability, training, and experience rank second to none.

When purchasing commodities, particularly engineering materials, the Government in most cases insists upon and obtains the highest commercial quality, and often a quality for which there is little or no commercial demand because of the high price.

The Committee believes that as natural resources become depleted it is inevitable that more research work will be necessary to allow the use of lower-grade materials, and that more and more high-grade engineering work will be necessary to fabricate machines and structures with low-grade, but increasingly expensive, materials.

This increasing necessity to use less material and more work and skill in supplying the needs of our material civilization is very apparent in Germany and other countries. Similar conditions are inevitable in this country, and commercial organizations are adjusting themselves to meet these conditions as they arise.

In view of the decreasing supply of material and the necessity of development and adaption of substitutes, and also considering the increasing costs of materials, the United States Government cannot afford to deprive itself of the best engineering brains and skill, which it must have in order to keep abreast of national progress and thus contribute to the efficient and economical operation of our Government.

It is a recognized fact in industry today that labor turnover is extremely expensive and in many instances unnecessary. In many lines the actual cost of training men for certain positions is known, and in order to obtain returns on such investment, in-

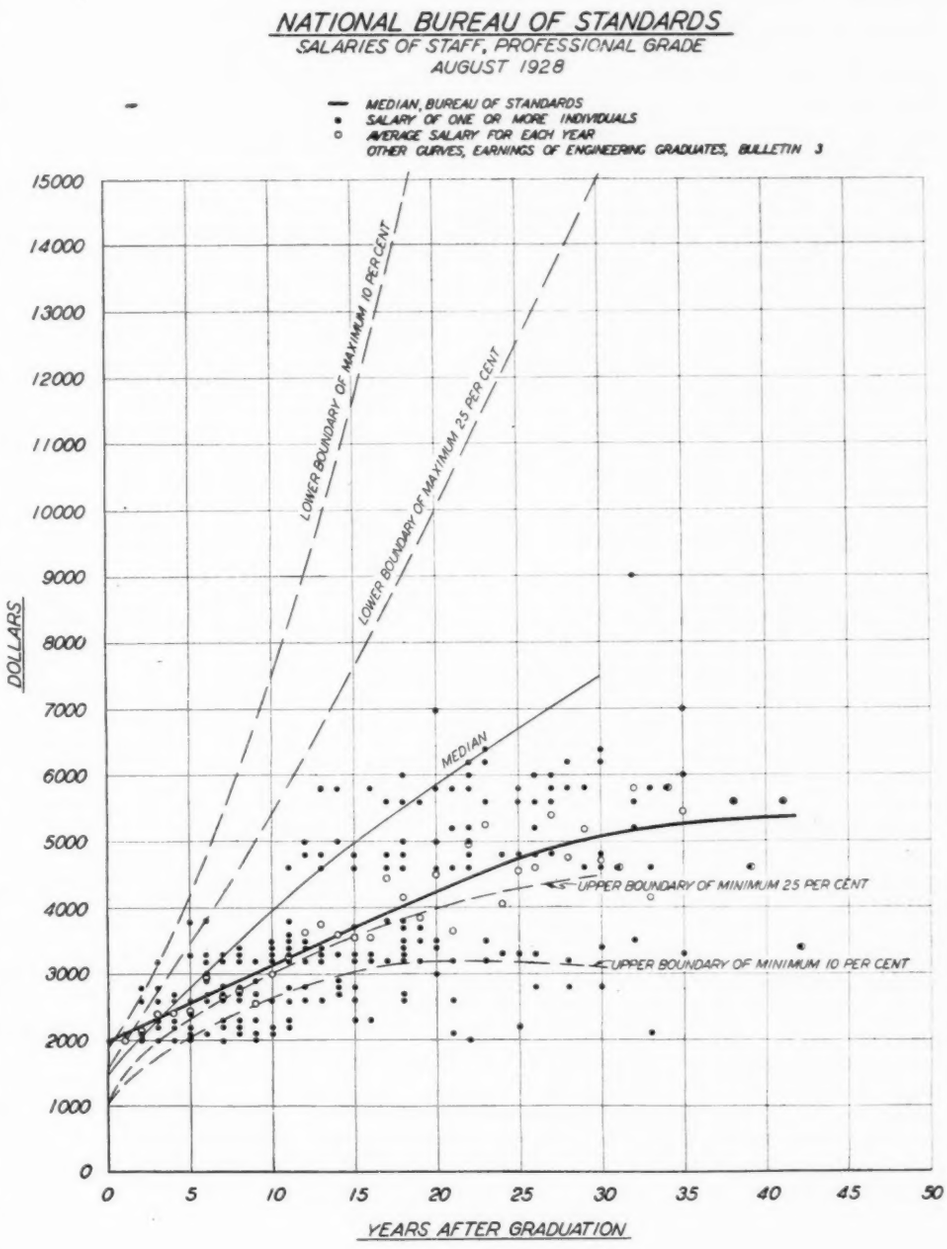


FIG. 4

dustries enter into long-term contracts with the trainees.

When "efficiency and economy," which are apparently the keynotes of the immediately past and present administrations, are fully analyzed and understood with relation to the engineer and his work in the Federal service, then will he receive adequate pay and a fuller opportunity to contribute to the material welfare of the people of the United States.

That the cost of securing the best engineering service will be insignificant compared with resultant benefits was shown by the analysis of Government expenditures made by Dr. E. B. Rosa and published in MECHANICAL ENGINEERING, February, 1921, Vol. 43, No. 2, p. 111. Dr. Rosa shows that for the fiscal year 1920, the United States Government spent only 4.21 per cent ($27,838,313) for research, education, and development, and only 11.75 per cent for public works ($77,743,451), such as rivers and harbors, Panama Canal, public buildings, reclamation, Alaska R.R., and post roads. The greater proportion of the expenditure for public work is for material and labor, the amount for technical and administrative work being very small.

The committee does not have the analysis of expenditures for more recent years. In all probability the percentages for research, education, etc., and for public work for the last fiscal year do not differ appreciably from those given by Dr. Rosa. The percentage of the total spent for engineering salaries is so small that even a large change in salaries would not change this percentage appreciably.

If the people of this country can be brought to understand their need for scientific and technical service of the highest order, there is no doubt but what the Federal service would attract and hold the most competent engineers in the country.

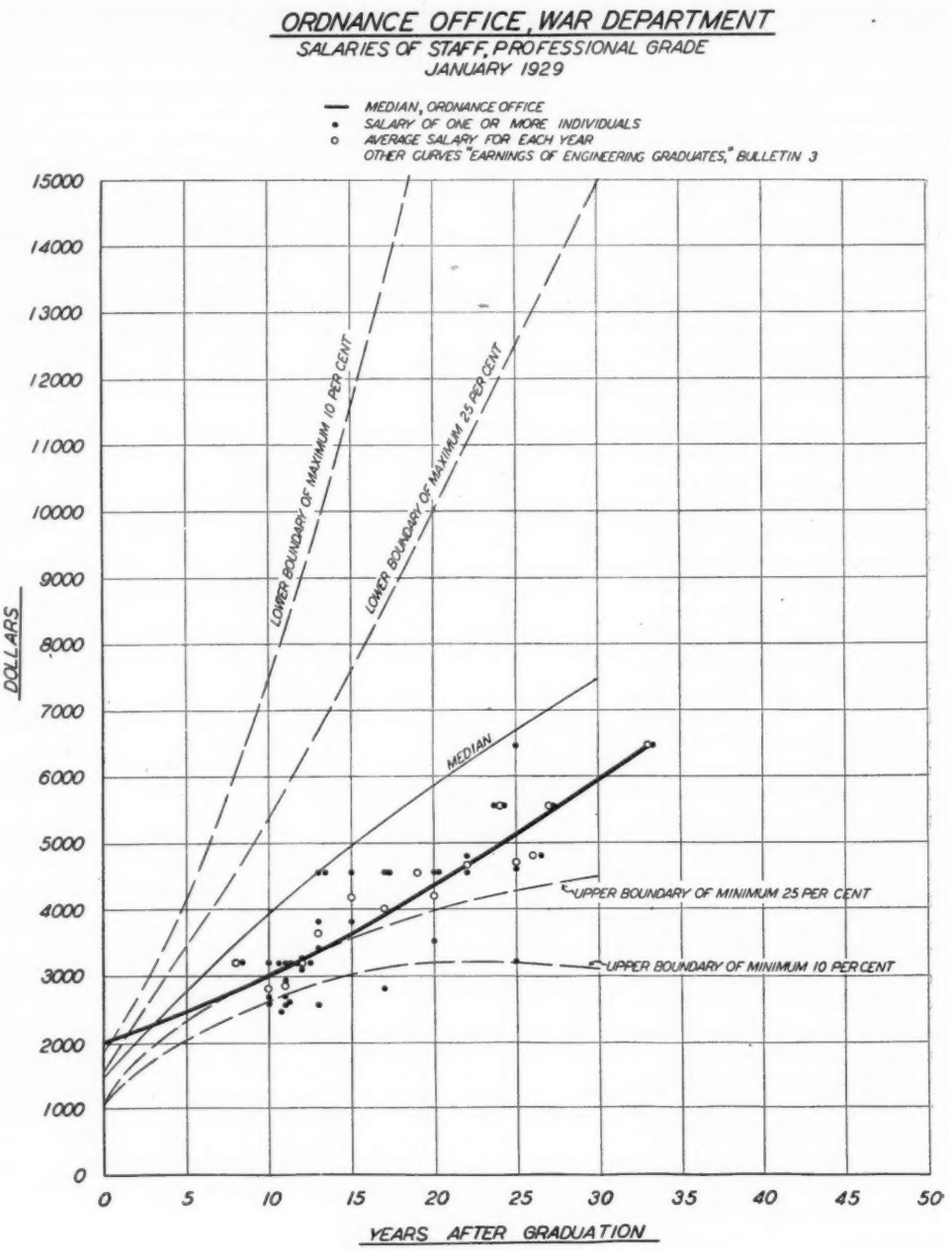


FIG. 5

CONCLUSIONS

Although there are many undesirable conditions affecting engineers in the Federal service which should be remedied to improve the efficiency of the service rendered the taxpayer and to economize public funds, the Committee desires to emphasize that:

1 Salaries of Federal engineers should be made commensurate with duties and responsibilities, and at least equal to those paid engineers outside the Federal service.

2 There should be no "Average of the Grade" restriction limiting promotion within the grade.

3 Retirement annuities should be sufficient to maintain employees in comfort, and at least equal to those paid by the larger industrial organizations.

Respectfully submitted,

H. L. WHITTEMORE, *Chairman* (Bureau of Standards)
I. J. FAIRCHILD, *Secretary* (Bureau of Standards)
ARTHUR ADELMAN (Ordnance Department, U. S. Army)
LAURENCE L. BEEBE (Bureau of Public Roads)
HARVEY BOLTWOOD (Interstate Commerce Commission)
ARTHUR H. CHASE (Naval Gun Factory)
O. P. HOOD (Bureau of Mines)
E. C. MAGDEBURGER (Navy Department)
O. C. MERRILL (Federal Power Commission)
M. E. PORTER (Patent Office)
LEONARD J. ROSE (Navy Department)
GEORGE F. WILLIAMS (U. S. Shipping Board).

Survey of Engineering Progress

A Review of Attainment in Mechanical Engineering and Related Fields

AERONAUTICS

Commercial Aviation in Soviet Russia

COMMERCIAL aviation in Soviet Russia is remarkable in that on many lines it comes into competition with the most primitive methods of transportation over great distances. The result is that the difference between the rapidity of communication by air and by land is startling in the extreme. Three organizations control commercial aviation in the country. The oldest is the Dereluft, which is a mixed Russian-German company operating a line of 2000 km. (1 km. = roughly $^2/_3$ of a mile), connecting Moscow with Berlin via Smolensk, Riga, and Koenigsberg. The same company operates the Leningrad-Koenigsberg line of about 1000 km., which is covered in a non-stop flight. This line operates regularly for postal service and the transportation of passengers, and forms the only existing air link between Soviet Russia and western Europe. The second organization is a Russian company, organized in 1923, under the name of Ukrvozdukput, with a capital of 400,000 rubles, which has since been increased to 3,000,000 rubles (about $1,200,000). This line centers about the Ukraine and connects Moscow through central southern Russia with the Caucasus and Persia, going as far as Teheran. The main line operates daily, the plane leaving Moscow in the evening a little after the arrival of the plane from Berlin. It reaches Baku in Transcaucasia the evening of the next day, covering a distance of 2560 km. in 24 hr. The ticket costs about 65 rubles. From Baku the line goes to Teheran, leaving twice a week during the entire year. The total length of the net covered by the company is 3310 km. In 1927, 2766 passengers were carried and in 1928, 3050.

The most important of the Soviet air organizations is the Dobrolyot, which operates in Central Asia and Siberia and has a total mileage of 12,000 km. Its main lines are:

A—Tashkent-Samarkand-Termez-Duchambe, 963 km. long. This distance is covered by air in 9 to 10 hr., by automobile in from seven days and longer, and by horse in any time up to three weeks.

B—The line from Charjuy via Khiva to Tashaus in 469 km. There are two other ways of traveling over this line. One is by steamer on the Amoo-Daria river, in from four to eight days. In the winter when the river is frozen the only way of traveling is by camels, which takes from 12 to 14 days. By airplane the same distance is covered in five hours. The planes leave the terminals six days a week.

C—The line from Frounze to Alma-Ata connects two locally very important towns, Pishpeck and Vierny. The distance between the two is only 240 km.; the region is very mountainous, has no good roads whatsoever, and can be covered only by horse in two days. In heavy rains or snows it is absolutely impassable. By airplane the same distance can be covered in $1^1/_2$ hr., and the planes leave four days a week.

D—This is economically and politically the most interesting line and extends from Tashkent in Russian Turkestan to Kabul in Afghanistan. The length of the line is 1100 km. The distance can be covered by horse in 30 days, by airplane in $8^1/_2$ hr. Technically this is a very difficult line to operate, because for 300 km. the plane has to fly over the Hindu-Kush mountain range. The planes fly, therefore, at a height of some 15,000 ft. New lines are being created all the time. For example, one from Alma-Ata to Semiplatinsk where it connects with a railroad line under construction to the main line of the Siberian Railroad. Another line goes way into Mongolia. And another line connects Irkutsk on the Siberian line with the Far North. The lines operate under the most severe conditions of temperature, and even −55 deg. cent. (−67 deg. fahr.) has not stopped them. Little things like storms, snow, and fog are not permitted to upset the schedules. From other information than that contained in the article here abstracted, it is known that the planes operate at capacity practically all the time and that there is a long waiting list.

Practically all the planes are of foreign make. However, lately a plane built entirely in Russia by the Russian engineer Kalamin is used. It is known as the "K-4." Several other types, however, have gone into commission in Russia, but it is not expected that, for some time at least, the lines will be operated entirely by material made in Russia. (*L'Air*, no. 236, Sept. 1, 1929, pp. 7–8, 1 fig., *gs*)

Coefficients of Efficiency of Certain Types of Aircraft

THERE has been considerable discussion of late in regard to the economic efficiency of flying. An attempt has been made to determine this by measuring the distances flown and determining the necessary ground organization, the density of traffic, and the economy of the various types of flying machines. As an essential basis for obtaining a higher efficiency, an increase in traffic was first considered, as well as the possibility of maintaining flight schedules at night and in fog. While, all these problems have been investigated from the point of view of traffic, the designer of aircraft has nevertheless kept more or less aloof from them. As a matter of fact, it would be impossible to obtain from what has been thus far published an answer to the question: "What requirements must be fulfilled in order to produce the most economic craft for flying under given conditions of traffic?"

It is natural to assume that concerns like the German Luft Hansa Company and the German Aircraft Experimental Laboratory have some such formulas, and it would be well, if they were to be published for the use of designers. The trouble is that today there are no generally recognized bases from which such an evaluation of aircraft could be made. It is claimed that German production methods can be improved and design made more precise. It is also claimed that American air services are more economical than the German, as in America 46 per cent of the expenses are said to be covered by traffic receipts, while in Germany only 14 per cent are so covered. [A footnote in the article states that the percentage covered were 26.7 in 1927 and 31.8 in 1928, but does not mention the country to which they refer. In this connection the abstractor would call attention to the fact that the author does not explain how the balance of 54 per cent of expenses is covered in America]. The question is as to whether the difference is due to the higher rates charged by American concerns or to the more economical design of American craft.

TABLE 1 COEFFICIENTS OF EFFICIENCY FOR VARIOUS TYPES OF

Nr.		Bayerische Flugzeug-Werke	Junkers	Dornier	Focke-Wulf	Caspar	Bayerische Flugzeug-Werke	Junkers	Rohr-bach	Junkers
1	Baumuster	M 18	F 13	Merkur	Möve	C 35	M 20	G 24	Roland	G 31
2	Motor-Nennleistung N_e . PS	108	280	500	480	500	500	840	960	1296
3	Zuladung L . . . . . kg	550	900	1400	1550	1660	2100	2620	3270	3500
4	Höchstgeschwindigkeit v km/h	140	192	190	201	202	219	197	200	200
5	Preis ohne Motor . in 1000 ℛℳ	37	60	63	56,5	68	100	168	200	315
6	Preis mit Motor . . in 1000 ℛℳ	43	75	89	81,5	94	126	213	251	384
7	Preis für 1 kg Zuladung . ℛℳ	78,2	83,3	63,8	52,5	56,8	60,0	81,4	75,8	109,5
8	$\frac{\text{Zuladung} \cdot \text{Geschwindigkeit}}{\text{Motornennleistung}}$.	650	618	531	650	669	920	614	682	540
9	Betriebstoff bei 400 km Q_{400} kg	77	146	263	239	248	228	426	480	648
10	Zahlende Last bei 400 km . kg	473	754	1137	1311	1412	1872	2194	2790	2852
11	Preis für 1 tkm bei 400 km . ℛℳ	227	249	196	156	167	168	243	225	336
12	Betriebstoff bei 800 km Q_{800} kg	154	292	526	478	496	456	852	960	1296
13	Zahlende Last bei 800 km . kg	396	608	874	1072	1164	1644	1768	2310	2204
14	Preis für 1 tkm bei 800 km . ℛℳ	135	154	127	95	101	96	151	136	217
15	Betriebstoff bei 1200 km Q_{1200} kg	231	438	789	717	744	684	1278	1440	1944
16	Zahlende Last bei 1200 km . kg	319	462	611	833	916	1416	1342	1830	1556
17	Preis für 1 tkm bei 1200 km ℛℳ	112	135	121	81,5	85,5	74,2	132	114,3	206
18	Preis für 1 tkm bei $Q_e = \frac{1}{2} L$ ℛℳ	109	136	120	81	84,5	65,5	132	113	203
19	Radius r_m bei $Q_e = \frac{1}{2} L$ . . km	1430	1230	1060	1300	1340	1840	1230	1360	1080
20	Preis für 1 tkm auf 120 000 km verteilt und zwar: a) 300 × 400 km ℛℳ	0,76	0,83	0,65	0,52	0,56	0,56	0,81	0,75	1,12
21	b) 150 × 800 „ „	0,90	1,03	0,84	0,63	0,67	0,64	1,01	0,91	1,44
22	c) 100 × 1200 „ „	1,12	1,35	1,21	0,81	0,85	0,74	1,32	1,14	2,06
23	d) bei $n r_m$ „	1,30	1,40	1,06	0,88	0,94	1,00	1,35	1,28	1,83

(Note. In this table, reproduced from the German, the commas should be read as decimal points. Translations of the items follow.)

1 Type of plane
2 Nominal rating of motor N_e, hp.
3 Load L, kg.
4 Maximum speed, v, km. per hr.
5 Price without motor, in thousands of Imperial Marks
6 Price with motor, in thousands of Imperial Marks
7 Price per kilogram of load, in Imperial Marks
8 $\frac{\text{Load} \times \text{speed}}{\text{Nominal output of motor}}$
9 Fuel for a flight of 400 km., Q_{400}, in kg.
10 Pay load for a flight of 400 km., in kg.
11 Price of 1 ton-km. for a flight of 400 km., in Imperial Marks
12 Fuel for a flight of 800 km., Q_{800}, in kg.
13 Pay load for a flight of 800 km., in kg.
14 Price per ton-km. for a flight of 800 km., in Imperial Marks
15 Fuel for a flight of 1200 km., Q_{1200}, in kg.
16 Pay load for a flight of 1200 km., in kg.
17 Price of 1 ton-km. for a flight of 1200 km., in Imperial Marks
18 Price of 1 ton-km. if $Q_e = \frac{1}{2} L$, in Imperial Marks
19 Radius r_m for $Q_e = \frac{1}{2} L$, in km.
20 Price per ton-km. for flights of 120,000 km. divided as follows: (*a*) 300 × 400 km., in Imperial Marks
21 (*b*) 150 × 800 km., in Imperial Marks
22 (*c*) 100 × 1200 km., in Imperial Marks
23 (*d*) at $n r_m$, in Imperial Marks

Since there are no formulas which permit making a direct and precise comparison between the two types, it may be worth while, as the author does, to institute a comparison of some of the best-known German and American types as they appear to an outside observer. It is to be emphasized that only a very crude comparison can be made, and that the results cited require some further explanation. In comparing these types of aircraft the author makes certain assumptions. The economic specification which he formulates is as follows: "It is required to produce a flying machine which is as cheap as possible to build, which can fly with the least consumption of fuel, at a maximum degree of safety, and carry to the greatest distance the greatest possible paying load." The following question must also be answered: "How great is the paying load that can be carried over a given distance, and what depreciation for various types of flying craft must be charged for each ton-kilometer of flight for given factors of first cost, safety, and deterioration?"

The information available for answering these questions are given by (1) known figures as to load, speed, motor output, and price of aircraft; and (2) by special conditions creating advantages or disadvantages for each given type of craft. It is only the factors covered by (1) that can be comprised in a formula covering all kinds of aircraft. The special conditions cannot be handled in the same way because of the lack of statistical data, and the following limitations therefore have to be considered in order to bring in the effect of special factors.

1 *Loading Space.* The space available to carry useful load is not taken into consideration in the formula evolved, because it is impossible as yet to compare existing craft from this point of view. Obviously, an airplane which has a larger amount of space available for this purpose will under otherwise equal

AIRPLANES

Stinson	Cessna	Matonay	Traveltin	Atlantic	Stinson
Junior	A/200	Ryan	6000	Universal	S M 1
110	200	200	200	200	200
445	481	643	731	855	945
176	240	202	205	190	200
29,20	41,16	51,24	54,60	60,00	52,50
65,6	85,6	79,8	74,6	70,3	55,6
712	576	650	750	810	946
62	83	99	97	105	100
383	398	544	634	750	845
191	265	236	215	200	155
125	167	198	195	210	200
320	314	445	536	645	745
114	164	144	127	116	88
187	250	297	292	315	300
258	231	346	439	540	645
94	149	123	104	93	68
92,4	149	123	99	87	58,8
1420	1150	1300	1500	1620	1890
0,64	0,88	0,79	0,72	0,67	0,52
0,76	1,09	0,96	0,85	0,77	0,59
0,94	1,49	1,23	1,04	0,93	0,68
1,09	1,43	1,33	1,24	1,18	0,93

conditions have an advantage over one that is not so fortunate in this respect.

2 *All-Metal or Mixed Construction.* This question is not considered either, in so far as it affects economy of operation. Mixed-type aircraft are cheaper to build, but more expensive when it comes to attendance and maintenance. The influence of this factor, however, is not very great, and it need be considered only when the data cover a period of years.

3 *Absolute Speed.* This likewise is not considered in the evolution of formulas expressing the economic efficiency of airplanes. It affects the calculation only to the extent that a greater speed implies a greater radius of action. Primarily, however, it is not important whether an airplane covers a stretch of 2000 km. in 10 hours or in 12 hours. The speed of the airplane in flight is so far superior to all the other elements determining the speed of traffic that the difference in speed of flight between the various types of planes has not as yet become a very material one. It may properly be assumed that in many cases a speedy plane can obtain higher fares and thus be more economical. The slower plane, however, has the advantage of slower landing speed and hence a higher factor of safety. It is not clear yet which of the two desiderata must be striven for.

4 *Motor Output and Maximum Speed.* In the formula the nominal rating of the motor is used. Essentially this is misleading and is apt to introduce an error into the formula. The proper way would be to consider the motor output as a function of speed of flight. The greater the difference between the nominal rating and the output in actual operation, the more economically the plane will work, all other conditions being the same. Since, however, no reliable data as to this difference for each type of plane have been published, there is nothing to do but to use the nominal rating, and consider the actual output of the engine during flight as one of those special conditions which are not included in the general formula.

It is because of the same lack of data that the maximum speed as given in the published specifications for each type of aircraft is considered and not the actual cruising speed. The smaller or greater difference between the two is again considered as one of those special conditions which must be taken into account in addition to the factors entering into the general formula.

5 *Multi-Motor Airplanes.* The question of comparing from the point of view of economic efficiency, a multi-motor airplane with a single-motor one, has not yet been satisfactorily answered. Some claim that a multi-motor plane is safer, while others deny that it is and point to the possibility of trouble due to the larger number of cylinders. It is significant that insurance companies, which presumably ought to know something about it, have not lowered insurance rates in favor of multi-motor planes.

6 *Safety.* As a yardstick for measuring the safety of the various types of planes, the premiums required by the insurance companies may serve. At least it is to be assumed that these companies have all the statistical data which are necessary to work out a scale of premiums. Comparatively slight reductions are made in rates for certain types of planes as determined by their use and consequent chances of breakage, but for the most part the premium is based solely on the first cost of the plane.

7 *Radius of Action.* The question as to what radius of action to assume in comparing the economic efficiency of planes is a difficult one to answer. If the radius of action is quite small, a correspondingly large pay load can be carried, and as the radius of action increases the pay load decreases. In order to do justice to the various types of airplanes, coefficients have been worked out for four cases wherein the radius of action was (1) 400 km., (2) 800 km., (3) 1200 km., and (4) where out of the total load one-half was pay load and the other half fuel, assuming that with this amount of fuel the plane will fly as far as possible.

8 *Weight of the Pilot.* This is not considered, or rather it is assumed to be part of the weight of the plane. It is impossible to give an exact figure for this in a formula. It may, however, be neglected when comparing the various airplane types since it is approximately the same for all of them.

9 *Fuel Consumption.* This is assumed throughout to be 0.25 kg. (0.55 lb.) per hp-hr.; no account is taken of lubricating-oil consumption.

COEFFICIENTS

Table 1 contains the coefficients collected with a view to the limitations already stated. Lines 1 to 6 give figures published for the various types of airplanes. Prices of American machines without motors are not given as the figures were not available. Lines 7 and 8 give a comparison, crude as it may be, of the performances of the various types. The lower the cost of the airplane is per kilogram of pay load, the more economical it would appear at first sight. The larger the product of load times speed divided by the nominal output of the motor, the better in general the craft may be assumed to be from the engineering point of view. A clearer view of the economy of operation under various conditions is obtained, however, only through the succeeding lines of the table, where the pay ton-kilometer

traffic is combined with the first cost of the plane. As the insurance premiums increase as a rule in proportion to the first cost, the depreciation reductions depending on this first cost together with safety considerations are expressed in a general coefficient. As regards depreciation, it should be noted that what we are dealing with here is not depreciation in the usual bookkeeping sense, but a factor which affects the total economic operation of the airplane under such assumptions as have been made above. Two basically different cases have to be considered here: (1) Depreciations referred to the number of flights of a given length, and (2) depreciations referring to the number of kilometers flown under various conditions. As regards the first, the basic question is as follows: How high is the first cost per ton-kilometer, i.e., the amount which must be included in the freight rate per ton-kilometer in order to cover depreciation on the airplane after the flights. For simplicity's sake it is assumed that depreciation is figured after the airplane has made 100 flights, and the figures in lines 11, 14, 17, and 18 have been calculated on that basis. These figures refer to radii of action of 400, 800, and 1200 km., respectively. The weight of the fuel, for example, is found to be

$$Q_{400} = \frac{N_e \times 0.25 \times 400}{v}$$

The pay load will then be $L - Q_{400}$, and the price per ton-kilometer is $\frac{\text{price} \times 1000}{(L - Q_{400}) \times 400}$. For the case where the radius of action is determined by $Q = {}^1/_2\ L$, the corresponding figure will be $\frac{\text{price} \times N_e \times 0.25 \times 1000}{(0.5\ Lv) \times 0.5\ L}$. This permits making a comparison. Let us take the case of the Focke-Wulf airplane, type Möve, flying 400 and 800 km. This would appear to be the most economical airplane for these distances, with its coefficients of 156 and 95, respectively. However, in flights of 1200 km. and those where the weight of the fuel is half the total load, the first place belongs to type M 20 of the Bavarian Aircraft Works with its coefficients 74.2 and 65.5.

In order to obtain, however, complete evaluation of these two types of airplanes in comparison with other types it would be necessary to take into consideration the special qualifications enumerated above, in particular the fact that the Focke-Wulf plane requires attendance costs while the fitness of type M 20 for very long flights has still to be determined. The order of merit of the other planes follows from the coefficients given. For example, for flights of 800 km., types M 18 and Roland seem to be equal, while type C 35 with a coefficient of 101 is more than twice as economical in operation as type G 31 with its coefficient of 217 (see line 14 in Table 1).

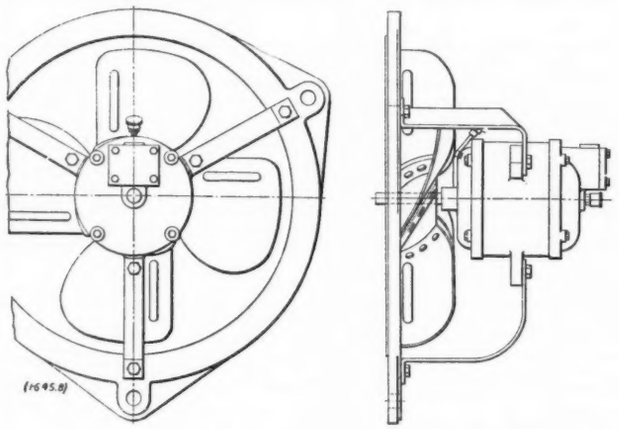
These assumptions, however, change materially if instead of the number of flights, we take as a basis of depreciation the number of kilometers flown. In order to obtain a value for this, the performance of an airplane for purposes of depreciation is assumed to be 120,000 km. of flight. This performance may be investigated for four different cases: namely, (1) 300 flights of 400 km. each; (2) 150 flights of 800 km. each; (3) 100 flights at 1200 km. each, and (4) as many flights as can be executed with the radius of action r_m determined by the condition that $Q = {}^1/_2\ L$.

While in the case of a given number of flights the amount of depreciation entering into freight rates increases with the increase of the length of flight when depreciation is fixed, the long flight is more expensive than the short one. This is due to the fact that in longer flights correspondingly less pay load can be carried. The figures for this are given in lines 20 to 23 of Table 1. From this it appears that the charge on freight rates slowly increases with increase of length of flight, with the exception, of course, of the case in which r_m is less than 1200 km., as, for example, in the case of types Merkur and G 31. For cases covered by (*a*) and (*b*) the type Möve stands first, while for cases (*c*) and (*d*) type M 20 excels all others listed. These two methods of determining depreciation work in a manner contrary to each other. With one method the longer flights are cheaper, and with the other more expensive, than the short ones. Which method of depreciation is the proper one cannot be determined with certainty without further consideration, and the selection has to be made on the merits of each individual case. It is, however, generally advisable in any event to charge a somewhat higher amount for depreciation on shorter flights. Table 1 permits, among other things, a comparison of German airplanes with American machines. The author calls attention to the fact that it is not clear whether American specifications give normal or maximum loadings. They probably give the latter, which makes the coefficients unduly favorable in their case. In any event, for example, the Stinson airplane, type SM 1, is highly economical. (Paul Reippel in *Zeitschrift des Vereines deutscher Ingenieure*, vol. 73, no. 42, Oct. 19, 1929, pp. 1513–1516, *cp*)

AIR MACHINERY

A New Extraction Fan

A COMPARATIVELY new field within the purview of the Factory Department of the Home Office is that comprising the handling of air charged with gases of a highly inflammable or



FIGS. 1 AND 2 LEACH-WOODS PROPELLER FAN FOR INFLAMMABLE GASES

explosive nature, such as those which obtain in cases where cellulose is employed. The tendency to impose greater restrictions on the use of extractor fans for dealing with air in such a state has led S. G. Leach & Co. Ltd., 26–30 Artillery Lane, London, E. 1, to bring out a fan having a flameproof electric motor and designed to meet the requirements of the Home Office and of the Mines Department, Sheffield. The fan is of the free-intake type, with a four-bladed propeller of a somewhat unusual type. The motor is completely protected, and the terminal box is also closed in, and has the cable entry tapped for a screwed conduit. A reference to Fig. 2 will show that the covers for the motor and for the terminal box are secured by setscrews, which can be tightened with box spanners in order to insure good joints being made. The flanges, moreover, are of considerable width, and are machined. Should the leakage of inflammable gases take place into the motor casing, any resultant flame would

be sufficiently cooled in its passage between the flanges to remove all danger of ignition of the surrounding atmosphere.

The motor may be supplied suitable for either alternating current, of single-, two-, or three-phase, or for direct current. The impeller has four blades of the shape indicated in Fig. 1. These blades are provided with an embossed stiffening rib near the straight edge, which effectually prevents whipping. The blades are secured to a machined conical boss, the formation of which prevents reentrant air currents when working against a resistance, and conduces to silent running with absence of vibration. Ball bearings are fitted to take both radial and end thrust, and the fans can be used either in the vertical or a horizontal position. A special grease-filled stuffing box is provided to prevent the leakage of air inward. The fan is at present manufactured in five sizes, ranging from a blade diameter of 12 in. to one of 30 in.

The employment of a fan with a protected motor is not, of course, necessarily restricted to the handling of air containing inflammable gases; such fans may be used for air laden with moisture, acid fumes, fine dust, or other substances likely to be deleterious to unprotected electrical machinery. Further, these fans may be used in connection with ducts, provided these are correctly designed, both as regards dimensions and lead. It is claimed that, installed in such a way, this type of fan will do the work of a centrifugal or cased type of fan at about half the current consumption of the latter, while its original cost is much lower. (*Engineering*, vol. 128, no. 3330, Nov. 8, 1929, p. 606, *d*)

ENGINEERING MATERIALS (See also Testing and Measurements: The Correlation of Fatigue and Overstress)

Locomotive Forgings

THE author deals with the various elements entering into the production of locomotive forgings and then proceeds to discuss their tensile properties.

Four tensile properties are usually measured in acceptance tests for steel forgings: the ultimate tensile strength, the yield point, the elongation in 2 in., and the reduction of area. For any given type of steel and for a given heat treatment these four properties must bear a definite relation to each other. Consider first a plain carbon steel normalized and tempered, and take the tensile strength as the basis property. If a number of forgings from various melts of steel, treated in different lots, are tested, it will be found that in spite of all reasonable care to obtain uniformity the values for the tensile strength will vary through a range equal to about nine or ten per cent of the mean value. Thus, if a minimum tensile strength of 85,000 lb. per sq. in. is specified, the average value will be about 89,000 lb. per sq. in. with a range between 85,000 and 93,000 lb. per sq. in. The variation will be due in part to variations in composition of the various melts, and in part to variations in heat treatment. Such variations in tensile strength occur not only between different forgings, but also between different parts of the same forging. In a recent study of the properties of forgings 32 tensile tests were taken from a forging $10^1/_2$ in. in diameter and about 50 in. long. All test specimens were taken from a standard position, that is, one half-way between the center and the outside. Twenty-five of the 32 tests gave tensile strength between 87,500 and 88,700 lb. per sq. in., indicating a high degree of uniformity in the forging. The highest and lowest values found for the tensile strength were 86,300 and 91,500 lb. per sq. in., respectively. The yield point stands in close relationship to the tensile strength, but before discussing values it is necessary to decide on how they are to be measured. For the present purpose yield point is taken to be the load per square inch at which with a uniform test-machine speed there is a definite drop of the beam of the machine. The value found for the yield point for any forging will depend on the speed at which the test machine is run. Fig. 3 shows the yield-point values for a number of specimens from one forging when tested with different test-machine speeds. The speeds given are those of the crosshead of the machine when running without a specimen. The thirty tests represented in Fig. 3 were all made with speci-

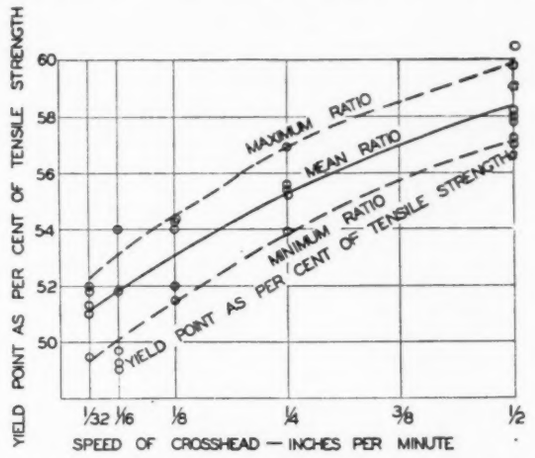


FIG. 3 CURVES SHOWING EFFECT OF SPEED OF TESTING ON YIELD POINT

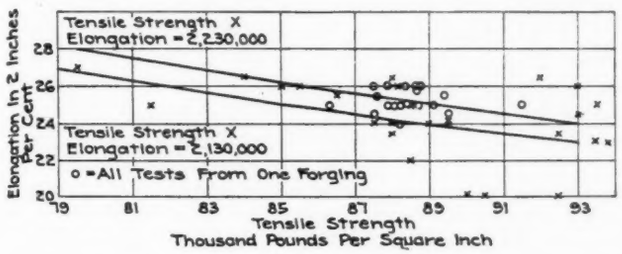


FIG. 4 CURVES SHOWING RELATION BETWEEN ELONGATION AND TENSILE STRENGTH

mens taken from the forging referred to above. This was made of acid open-hearth steel having the following composition:

	Per cent
Carbon	0.51
Manganese	0.63
Silicon	0.26
Phosphorus	0.030
Sulphur	0.036

With a test-machine speed of $^1/_8$ in. per min. the yield-point values vary from 50.3 to 54.0 per cent of the tensile strength. These are all tests from a single forging. If a number of forgings are compared the range will be somewhat wider, say, from 50 to 55 per cent of the tensile strength.

The elongation and reduction of area also depend on the tensile strength, but by an inverse ratio. Fig. 4 shows the values of elongation and tensile strength plotted for a number of tests. The average values are well represented by the curve, tensile strength $\times$ elongation equals 2,230,000, while the minimum values are not very different from the curve, tensile strength $\times$ elongation equals 2,230,000. It is evidently proper in drawing specifications to take into account this natural tendency for the elongation to increase as the tensile strength goes down. For example, if a specification is to be drawn for normalized and tempered carbon steel with a minimum tensile strength of 85,000

lb. per sq. in., it is to be expected, as shown above, that actual tensile-strength values will range from 85,000 up to about 93,000 lb. per sq. in. Then a decision should be made as to the minimum elongation which will be accepted with the maximum tensile strength. For example, for forgings not over 9 in. in diameter it would be proper to specify that with a tensile strength of 93,000 lb. per sq. in. the elongation in 2 in. should not be less than 23 per cent. Then for lower values of the tensile strength proportionately higher values of the elongation should be required. The following table shows the minimum values for the elongation which, on this basis, would be acceptable for each value of the tensile strength.

Value of tensile strength in lb. per sq. in.	Minimum acceptance value of elongation, per cent
85,000	25.0
86,000	24.8
87,000	24.5
88,000	24.2
89,000	24.0
90,000	23.7
91,000	23.4
92,000	23.2
93,000	23.0
Over 93,000	23.0

This relation between elongation and tensile strength can be obtained by specifying that the quality factor, or tensile strength multiplied by elongation, shall not be less than 2,130,000. The use of this quality factor to provide a sliding scale for the elongation required is preferable to merely specifying a flat figure for the minimum elongation to be acceptable for all tensile strengths. If, for example, a flat minimum elongation of 23 per cent were specified, all forgings with an elongation of 23 per cent would be acceptable, whether the value of the tensile strength was 93,000 or only 85,000 lb. per sq. in. For the former the quality factor, tensile strength multiplied by elongation, has the value 2,130,000, while for the latter its value drops to 1,960,000. There is no advantage to the manufacturer in allowing forgings of this grade to have lower quality factor values at the lower tensile strengths, and it is therefore desirable to give the user the protection afforded by specifying that the elongation shall be determined from the sliding scale with a constant quality factor. In the case under consideration this would be done by specifying that the elongation in per cent shall not be less than 2,130,000 divided by the value of the tensile strength, and that where the tensile strength is more than 93,000 lb. per sq. in. the elongation shall not be less than 23 per cent. (Lawford H. Fry in a paper presented at the Annual Convention of the American Society for Steel Treating, Sept. 9–13, 1929; abstracted from preprint, 33 pp., 13 figs., *ge*)

FUELS AND FIRING

Temperatures for Rapid Self-Heating of Powdered Coal and the Semi-Coke Made Therefrom

INCIDENTAL to a cooperative investigation with the Carnegie Institute of Technology and the International-Combustion Engineering Corporation on the burning characteristics of a powdered coal and the powdered semi-coke made therefrom, the U. S. Bureau of Mines has determined the relative temperatures at which rapid self-heating occurs in these two fuels. Determinations were made on various screen sizes of the two fuels. Chemical analyses on the different sizes were made in the Bureau's Coal Analysis Laboratory, of which H. M. Cooper is in charge. The true densities were determined by the method given in Bureau of Mines Technical Paper No. 8.

Although it was realized at the outset that these measurements would give at best only a rough indication of the liability of the two powdered fuels to heat spontaneously under practical storage conditions, it was felt that the results would be of interest in comparing the properties of the fuels. It would probably have been said on the basis of previous knowledge that the semi-coke would be far less liable to heat spontaneously. The temperatures at which, under the conditions of measurement, appreciable self-heating occurs, can doubtless be regarded as a relative measure of oxidation, and thus of the rate of self-heating, of the two fuels. The relative rates of oxidation of the two fuels at lower temperatures (normal storage temperatures), if they could be determined readily would not necessarily be the same. That is to say, the temperature coefficient of the rate of oxidation of one fuel may differ enough from that of the rate of oxidation of another fuel to reverse the relation between the rates at a different temperature. As applied to practice, Davis

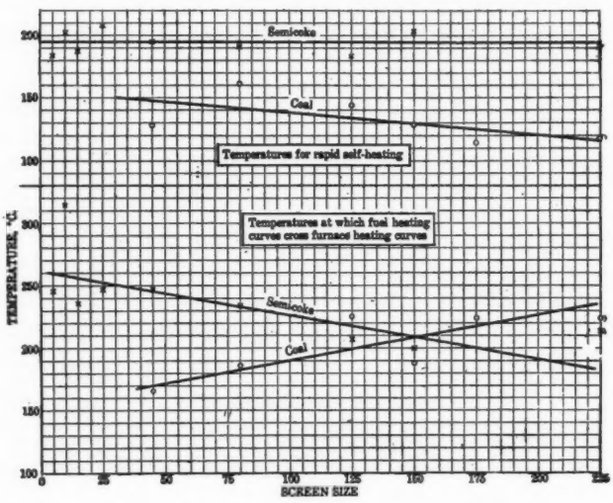


FIG. 5 IGNITION TEMPERATURE FOR COAL AND SEMI-COKE

and Reynolds point out that the storage conditions themselves are of the greatest importance in determining liability to spontaneous heating.

Although other work has indicated that no consistent differences between different sizes of the same fuel are to be found by this method, it was thought well to check this finding in the present work. It is certainly to be expected that a lower temperature would be obtained with the finer sizes, other things being equal. Actually, however, other effects doubtless enter in, the most important of which would seem to be (1) difference in chemical composition in the different sizes, (2) agglomeration of the particles as they become heated, and (3) different overall thermal conductivities for samples of fuel of different sizes. With coal, the higher rate of distillation of gaseous products from the samples of finer size (a process accompanied by absorption of heat) tends to offset the greater amount of exothermic, oxidation reaction. With an exothermic reaction having a high temperature coefficient (as the oxidation of coal and coke doubtless has at these low temperatures) and taking place in a mass of material of uncertain heat conductivity, it is not surprising that certain effects are masked by others.

The phenomenon of glowing mentioned by Arms was observed in this work. It occurred very close to the temperature at which the fuel began to self-heat rapidly. The temperatures observed in the present work are considerably below any of those observed by Arms for the glow point. Differences in the nature of the fuels tested and in the method of testing doubtless account for this.

At the top of Fig. 5 are plotted the temperatures at which there is a break in the heating curves, against the screen sizes. From this figure the evidence for variation of temperature with size of particles seems uncertain. Likewise there is no parallel between temperature and size or chemical analysis. The temperatures for coke seem, however, consistently higher than those for coal.

If the temperature at which the heating curve for the fuel crosses the heating curve for the furnace (the point taken by Wheeler) is plotted against particle size, the curves shown in the lower part of Fig. 5 are obtained. The smaller sizes of semi-coke would seem to self-heat at a lower temperature than the larger sizes. The reverse is true for the coal. It is possible that this condition could exist because of the fact that the semi-coke particles, after heating, are still of approximately the original size; that is, they do not stick together as do the coal particles. Thus, when the fuel particles *at the point where rapid self-heating starts are finer*, the temperature for self-heating is lower, as would be expected.

The point at which a definite break in the fuel heating curves occurs would seem to be somewhat less readily determined than the point (as used by Wheeler) where the fuel and furnace curves cross. The results by the two methods lead to somewhat different conclusions. It appears, however, that the results in either case are scarcely accurate enough to permit an unequivocal statement to be made in regard to the effect of particle size. (F. A. Hartgen and David F. Smith, both with the Bureau of Mines, Pittsburgh Experiment Station, in *Reports of Investigations, U. S. Bureau of Mines, Serial No. 2960*, Oct., 1929, mimeographed copy, 5 pp., 18 figs., *eA*)

INTERNAL-COMBUSTION ENGINEERING

Fuel Pumps for Airless-Injection Engines

THIS is a description of a pump built by the R.E.F. Apparatenbau, of Stuttgart, Germany, which it is claimed is suitable for many types of Diesel engines of divergent design.

The general principle of the pump is seen in Fig. 6. The frame *A* carries the pump body *B*, an adjustable nut *C* being provided. The pump-operating cam is at *D*, with a roller *E*, *F* being the pump-actuating member under spring loading. *D* is the pump piston, guided in the sleeve *H*, this latter being supported on a shoulder in the upper part of the casing, and held in position by a valve sleeve *K*. Above this is a nipple to which the pump delivery pipe is connected, and there is a nut at the top which closes the upper end of the pump casing. Communication through the side of the pump casing *B* with the suction pipe *L* is effected through a small passage *M* with the sleeve *H*. In the piston itself is a wide peripheral groove, through which the aperture *L*, also the duct *M*, communicates, allowing access between the suction pipe and the interior of the hollow pump piston. At the upper end of the pump piston is the suction valve *P*.

It will be noted that the valve sleeve *K* has a recess and forms a space above the guide sleeve *H*, while it is formed with a seating for the pressure delivery valve *Q*. There is a slot in the pump casing *B*, admitting a lever arm *R*, which is held in such a position that it can be rotated between the end of the sleeve *H* and the lower part of the pump casing. The bottom portion of the pump piston is flat, and it enters into a corresponding aperture in the boss of the lever *R*. Thus the piston is compelled to participate in the rotary adjustment of the boss. The piston itself is attached to the actuating member *F* by two opposed lugs *S*, which are admitted through a keyhole aperture into an undercut recess in the end of the actuating member. When the engine is running normally the position of the arm *R* is such that it may be turned through 45 deg. in either direction, while still maintaining connection between the piston and the actuating member.

The method of operation may now be explained. When the piston descends the valve *P* opens and fuel flows from the suction pipe into the compression space *T*; when the piston *G* begins to move upward the suction valve closes and the valve *Q* is opened, fuel being thence pumped into the cylinder via the fuel valve through the fuel delivery pipe at the top. As the piston moves upward the aperture *U* will, at a certain point, place the compression space *T* in communication with the suction pipe *L*, so that the flow of fuel to the cylinder will cease.

The edge of the sleeve *H* is helical, so that by a rotary movement of the pistons the aperture *U* can be made to register communication at various points of the upward or pressure stroke, and the duration of the delivery of oil can be controlled according to the load on the engine. The lever arm *R* can be coupled to the governor by automatic control.

It is stated that with these pumps the fuel consumption with engines of moderate size is 178 grams per b.hp-hr., which is equivalent to 0.395 lb. This figure has, it is claimed, been attained with two-cylinder two-stroke engines of the crank-chamber compression type. (*British Motorship*, vol. 10, no. 116, Nov., 1929, p. 302, 4 figs., *d*)

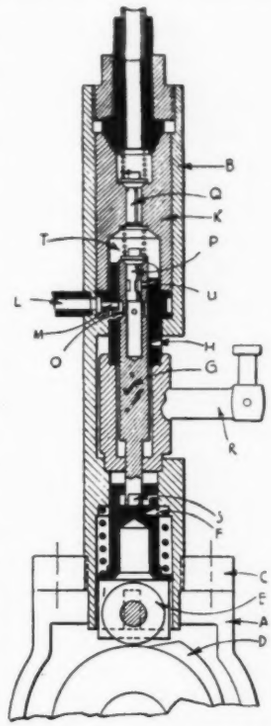


FIG. 6 R.E.F. FUEL PUMP FOR AIRLESS-INJECTION ENGINES

The Cochran Waste-Heat Boiler as Installed With a Doxford Engine

THIS is the boiler that has been installed in combination with the 1500-b.hp. three-cylinder opposed-piston two-stroke engine on the motorship *Sheaf Holme*. Exhaust-gas boilers have been widely used in conjunction with four-stroke-type Diesel engines, but less frequently in two-stroke engines on account of the low temperature of the exhaust gases of the latter. In this case it is claimed successful results were obtained.

This is due to the efficient scavenging system of the engine whereby the exhaust gases are not unduly cooled (the temperature being in the neighborhood of 670 to 700 deg. fahr.), and to the large heating surface of the boiler which is of the usual Cochran type, but specially designed for simultaneous oil firing and waste-heat recovery.

The boiler has entirely separate nests of tubes and separate funnels for the two purposes. This arrangement prevents all possibility of an explosion due to the ignition by the exhaust of oil vapor and air in the furnace or flues.

The boiler has a single nest of ordinary standard tubes in the oil-firing part, which, with the furnace, give a heating surface of about 500 sq. ft.

The tubes for the waste gases consist of two nests of smaller-diameter tubes, one above the other, the gases being passed first through the top nest and returned through the lower nest. The heating surface of the waste-gas part of the boiler is 1390 sq. ft. All three nests are between the same pair of tube plates.

Before installation in the *Sheaf Holme* the boiler was tested at the Doxford works, coupled to a three-cylinder engine of 2000 b.hp., and evaporated 0.84 lb. of water at 60 deg. fahr. to steam at 100 lb. per sq. in. per engine b.hp. developed. The back pressure produced by the boiler was low, being about 8 in. of water, or 1/3 lb. per sq. in.

The drop in temperature of the exhaust gases through the boiler was rather more than 300 deg. fahr. and the final temperature was 400 deg. fahr., as shown in a graph in the original article. The water circulation was good, the temperature of the water at the bottom, when firing with exhaust gases only, being very little below that of the water surrounding the tubes.

The *Sheaf Holme* is a vessel of 8700 tons deadweight. The fuel consumption on the first voyage worked out at 5.35 tons per day for the main engines, which, it is said, is practically 20 per cent better than the results obtained with similar vessels but without waste-heat reclamation. The following steam auxiliaries were in use:

One 12½ kw. dynamo	Continuously
One general-service pump	Continuously
One bilge pump	Total 17½ hr. for the voyage
One fuel-transfer pump	Total 13 hr. for the voyage
One compressor	Total 7½ hr. for the voyage
One Sharpless purifier	Total 97 hr. for the voyage
One distiller	Total 41 hr. for the voyage
One evaporator	Total 42 hr. for the voyage
One refrigerator	Total 81 hr. for the voyage
One steering engine	When required
Quantity of distilled water used	Total 3 tons for the voyage

It is recorded that had the vessel been without the Cochran-Doxford combination waste-heat system, dealing with the exhaust from the main engine, the total consumption of fuel would have been increased by 1½ tons per day, making a total expenditure for all purposes of approximately 6.8 tons daily.

The result in overall consumption per b.hp-hr. is worth noting. Taking the average power at 1600 i.hp. as given, the consumption for all purposes at sea is 0.312 lb. per i.hp-hr.; and as this class of Doxford engine presumably has a mechanical efficiency not less than 85 per cent and probably higher, the overall consumption of fuel is apparently not more than 0.365 lb. per b.hp-hr. while the ship is at sea. (*The British Motorship*, vol. 10, no. 116, Nov., 1929, pp. 311–312, 5 figs., *d*)

METALLURGY

Lathe's Nickel-Refining Process

A NEW method for the separation of nickel from copper and precious metals in nickel-copper matte is described here. The process, which is not yet in operation, is based on two facts. In the first place, it has been found that in mattes containing in addition to nickel both copper and iron, nickel sulphide goes very easily into solution along with the iron in acids of moderate strength. It proved possible to extract practically the whole of the nickel by this method from mattes containing only 5 per cent of iron. Since, however, any iron remaining in the matte is dissolved with the nickel and would normally have to be removed at a later stage, means had to be found of still further increasing the solubility of the nickel sulphide, which would permit a reduction in the percentage of the iron in the matte treated. This was attained by giving the material a very fine crystalline structure by rapid cooling, which in turn was attained by granulation in water. The solubility of the nickel sulphide constituent of the matte was found to have been markedly increased by this procedure, so much so that it became possible by treatment with warm acid of moderate strength to dissolve the nickel almost completely within a few hours, even when no more than the ordinary fraction of 1 per cent of iron was present. (Frank E. Lathe in a paper delivered before the 12th Dominion Chemical Convention, Toronto, May, 1929; abstracted through *Canadian Chemistry and Metallurgy*, vol. 13, no. 6, June, 1929, pp. 174–176, *d*)

POWER-PLANT ENGINEERING

A Double-Rotation Turbine

IN A MODERN steam-turbine design there are two conflicting requirements. One is of the specific speed, leading to small physical dimensions and favorable conditions of tempera-

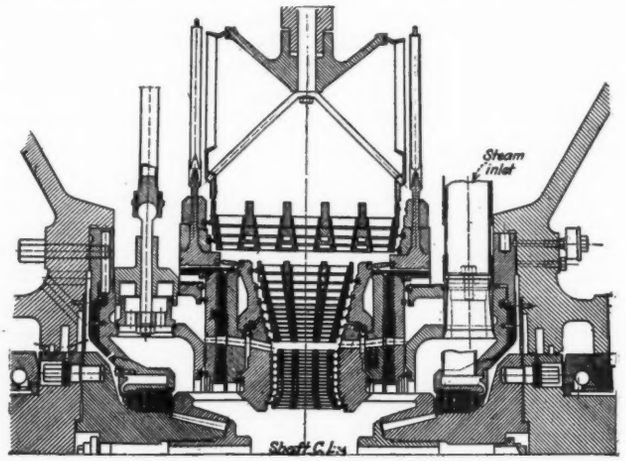


FIG. 7 OLD-TYPE 14,000-KW. RADIAL-FLOW TURBINE

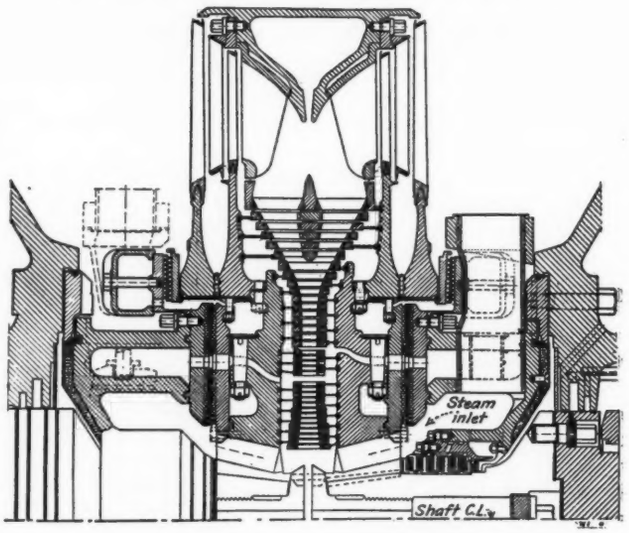


FIG. 8 MODERN CONSTRUCTION OF A 14,000-KW., 3000-R.P.M. RADIAL-FLOW TURBINE

ture distension. The other is a large discharge area, leading to small discharge losses. This area varies roughly as the inverse square of the speed for constant mechanical properties of the blade material, so that a high specific speed and a large discharge area are difficult to combine. The modern steam-turbine designs represent compromises with the major problem of increasing the discharge area to a maximum for each type of construction. One of the ways of solving this problem is shown by the Stal turbine of the radial-axial type. This turbine is of the double-rotation type and consists, in its original form, of two intermeshed systems of blading rotating in opposite directions; thus the ordinary

systems of stationary blading are replaced by rotating systems, so that the relative speed is twice the speed of rotation of each end.

In this form the requirement of a high specific speed was fulfilled, but it was not until the addition of axial low-pressure systems of ordinary blading that the requirement of a large discharge area was met. The steam upon leaving the radial system of blading is divided into two equal parts, and after expanding through the low-pressure stages it discharges directly to the condenser in a naturally wide passage without obstructions.

Fig. 7 shows a cross-section through the blading of a 14,000-kw. 3000-r.p.m. turbine of this type in its original form. Fig. 8 shows a similar cross-section of a modern turbine of the same size. A comparison between these cross-sections shows the more important improvements made in the detail construction of blading.

The possibilities of this turbine with regard to steam economy are best illustrated by the quality factor.

In England and in America the quality factor is usually expressed as

$$k = \sum \left(\frac{d}{10}\right)^2 \left(\frac{n}{100}\right)^2 = 10^{-6}\, n^2 d^2$$

where n is the r.p.m. and d the mean diameter in inches of each rotating blade ring.

In those turbines of ordinary type where the attempts to improve the steam economy have been carried the farthest, it has been possible to attain values of the quality factor of $k = 483{,}000$. For example, a turbine shown in Fig. 2 of the original article has $k = 463{,}000$. Both of these turbines represent extreme designs involving considerable complications in the general construction.

In the Stal turbine a value of $k = 455{,}000$ is entirely normal for 3000-r.p.m. machines; for 1500-r.p.m machines, values of $k = 680{,}000$ are obtained with a normal construction.

Until recently it has been the general opinion that the radial-flow turbine is limited inherently to small capacities. This conception might have been correct for the turbine in its original form, but the modern Stal turbine, where the radial turbine has been combined with an axial low-pressure turbine, is particularly suitable for construction of large units.

A feature that is closely associated with this question is the fact that the turbine is particularly free from thermal distortions. This is due to the small dimensions of the turbine, and to the favorable temperature distribution. The largest units that have been in operation for any considerable period of time—14,000-kw. at 3000 r.p.m.—are started regularly by opening the throttle wide.

The small dimensions contribute to another important advantage, namely, low cost of the foundation structure. Fig. 3 of the original article shows a typical arrangement that can be maintained in its general form for all sizes. The turbine cylinder is built directly on the top of the condenser, and the two generators are overhanging, with flexible supports to carry their weight. Thus the stator material of the generators, the exhaust of the turbine, and the condenser are all taking part in the foundation function, so that additional material for this purpose is superfluous. This not only contributes to low cost, but to accessibility to the auxiliary equipment. In addition it provides a dynamical machine system in which it is particularly easy to guard against vibration troubles, troubles due to thermal expansions, and permanent changes in the supporting groundwork.

There is now under construction a 50,000-kw. 1500-r.p.m. unit for installation at Västerås, Sweden. This is the largest unit actually under construction, although designs have been made for units of over twice this size. The span of the turbine room in this plant was selected originally for a 15,000-kw. unit as the maximum size. The new 50,000-kw. unit occupies an axial length equal to that of the comparatively recent 15,000-kw. 3000-r.p.m. axial turbine of ordinary construction. (A. O. Wiberg, one of the designers of the turbine, in *Power*, vol. 70, no. 20, Nov. 12, 1929, pp. 756–759, 12 figs., *d*)

The General Trend of Steam-Turbine Development by the General Electric Company

THIS paper deals primarily with the economic aspects of power generation. The author points out that the growth of the past ten years has borne remarkable witness to the faith of the industry in the dictates of pure theory.

Year after year pressures and temperatures have been pushed up by central-station constructors with perfect confidence that never-before-realized economies would be effected. The only factors of uncertainty which had to be explored in the course of this growth were the cost of accomplishment and the degree to which the refinements of design dictated by theoretical considerations would be warranted in reduced cost of the finished product.

Double-flow units apparently gave way to single-cylinder machines for a time, but recently size requirements have developed to such a degree that this type has come again into play. The regenerative cycle has been developed until now as many as five points of extraction are used for giving a highly regenerative heat balance.

The economic significance of this development is twofold. At one and the same time it decreases the fuel consumption of the turbine per unit of electric energy generated, and enables the

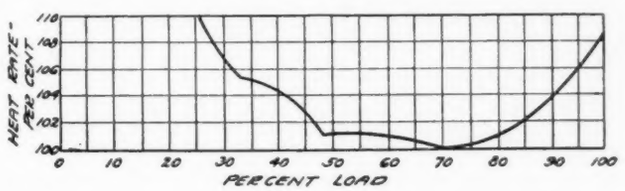


FIG. 9 HEAT-RATE–LOAD CURVE REPRESENTATIVE OF MODERN TURBINE PRACTICE

same size of turbine to handle a distinctly larger capacity for the same investment. The improved heat efficiency may be thought of as due to the recovery of considerable quantities of low-grade heat transferred to the returning liquid circulation and relieving the furnace of a corresponding duty. The increased capacity available from the same turbine investment may be easily appreciated by noting that the condensing plant is, with the regenerative process, distributed through a number of units and able to draw steam from several points of the turbine shell instead of having to receive it through a single congested passage. The process thus enables the drawing of considerable quantities of excess steam through the shorter buckets of the turbine, which are easily designed because the stresses in this case do not form any limitation and the additional cost is almost negligible.

Modern turbines are sold on a heat-rate–load-curve basis adapted to the requirements of the purchaser so as to provide him with the best "integrated" efficiency, i.e., the lowest heat consumption by the month regardless of the value at any individual point. Fig. 9 exhibits the heat-rate–load curve for a machine of the sort described and shows, between 47 and 85 per cent load, a heat rate rising not more than two per cent above the most economical condition at 70 per cent of the maximum capacity.

This tendency has also had a sort of double significance because the provision of a reserve capacity at slightly poorer efficiency, to be used only on occasions, not only enables a better monthly fuel report to be made, but also enables the raising of the kilowatt capacity rating of the entire station, with consequent

reduction in investment charges per unit of installed capacity.

Resuperheating is also finding increased favor with purchasers of turbines. The 1929 total represents nineteen units averaging just over 60,000 kw. capacity each. The high-pressure development has also powerfully assisted the application of re-super-heating.

The first large step toward higher pressures occurred simultaneously with the installation of the first resuperheating unit and also with the first large compound turbine. The use of higher pressures practically necessitates the use of the resuperheating cycle. A single expansion starting with high initial pressure would result in excessive moisture in the last stage of the turbine. Therefore, expediency as well as economic reasons dictated the resuperheating practice.

The first turbines installed to operate with this cycle were single-cylinder machines with provision made to take the steam from the shell at an intermediate pressure, return it to the boiler room for superheating, and then return it to the turbine shell for its final expansion. At practically the same time a cross-compound unit was installed to operate under closely similar conditions.

The tandem-compound machines as originated in 1925 were similarly arranged, except there were two shells and two rotors all in line, the resuperheating being accomplished between the shells.

However, the cross-compound machines have advantages particularly adaptable to use with high initial pressures and the resuperheating cycle, because the cross-over piping provides a convenient point for resuperheating and the shafts can be run at different speeds, which has been found to contribute toward a high mechanical efficiency.

Thus at 1200 lb. per sq. in. initial pressure, the high-pressure element operates at 3600 r.p.m. and the low-pressure element at 1800 r.p.m. These improvements also tend to give a larger output in kilowatts for the same investment in turbine and condensing plant, because of the additional available energy in the heat cycle per pound of steam. [Ernest L. Robinson (Mem. A.S.M.E.), Turbine Engrg. Dept., General Electric Co., in a paper delivered at the World Engineering Conference, Tokyo, Japan, October-November, 1929; abstracted through *General Electric Review*, vol. 22, no. 11, Nov., 1929, pp. 638–643, 8 figs., *gc*]

SAFETY (See Air Machinery: A New Extraction Fan)

SPECIAL PROCESSES

Hollow and Ring Forgings—Hollow Rolling Mill

THIS article describes the methods and apparatus employed by John Brown & Co., Ltd., Sheffield. The trepanning operation was executed on an ingot 52 in. in diameter, and 6 ft. 6 in. long. The size of the trepanned hole is 21 in., the core being 15½ in. in diameter. The machine used consists of two large V-blocks on which the ingot rests in line with large hollow boring bars mounted on lathe-type beds at each end of a long bedplate. The V-blocks are adjustable for center distance to accommodate ingots of varying length, the ingots being held in position by strong rolling-type chains which are anchored at one end and have a drawbolt at the other. The ingot is ready for forging directly after trepanning and inspection. The forging is carried out under a press of 6000 tons capacity. With a press of this size it is possible to forge ingots 96 in. across the flats by about 12 ft. long and weighing up to 143 tons. The maximum stroke or vertical movement of the crosshead is 10 ft., but the maximum forging stroke, i.e., bite of the top tool into the forging, is 10 in. with two intensifiers working, or 5 in. with only one intensifier in action, per stroke of the intensifier. Power is obtained by means of two steam-hydraulic intensifiers.

In the case of large ring forgings, which are produced up to a point on the same lines as ordinary cylindrical-drum and turbine-drum forgings, the final sizing operation is accomplished on a hollow rolling mill, which is illustrated in Fig. 10. This is the only mill of its kind in Great Britain, and is seen rolling a 48-ton ring 17 ft. 6 in. diameter by 7 ft. 6 in. wide and 5 in. thick in the walls. The ring is expanded to this diameter in the rolls n two heats, after having been expanded in the 6000-ton press to about 3 ft. diameter in the bore.

To describe the process, it may be said that the mill consists, in its essential details, of two main rolls with suitable guide rolls. The forging rests on the bottom two guide rolls and the bottom main roll, while the top main roll lies under the drum to be rolled. This top roll, which is seen at *A*, has a longitudinal sliding motion hydraulically operated to permit the drum being put into position, after which the roll is again moved into its place inside the drum. The bottom main roll has a vertical motion actuated by hydraulic power. The rolls are rotated by 12,000-hp. engines, and by pressing the bottom roll upward the ring is squeezed between the two rolls, gradually reducing the wall thickness and expanding the diameter to the required size.

The process for boring drum forgings described in the original article is, however, somewhat different. An interesting feature

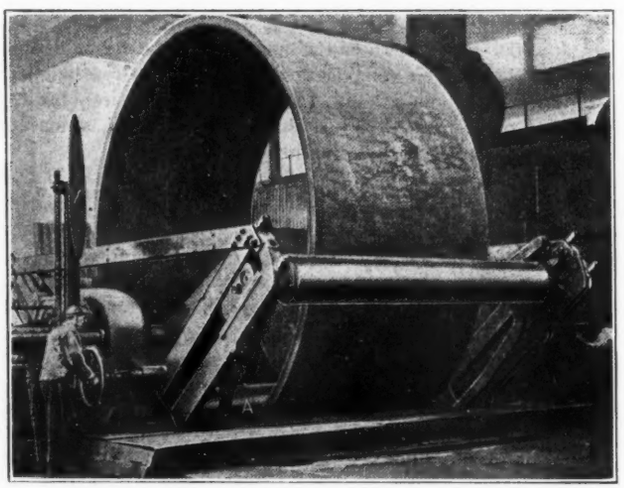


FIG. 10 HOLLOW ROLLING MILL FOR LARGE RING FORGING

of this process is the boring of the manhole, particularly noteworthy in that it trepans an elliptical hole directly. For turning the outside diameter and the two ends of the forgings, large center lathes are used. A feature of one of the latest machines which was built by G. & A. Harvey, Govan, Glasgow, is that it is designed to take advantage of the new high-speed cutting alloys. It is an electrically operated machine, swinging up to 66 in. diameter by 51 ft. long between centers, and weighs 124 tons. Drive is supplied by a 160-hp. motor, but the machine is capable of transmitting the full power of a 300-hp. motor at speeds down to 4¼ r.p.m. With the working dimensions and spindle speeds available, it is possible to turn pieces 5 ft. 6 in. in diameter at 23 ft. per min. Alternatively, cutting speeds of 200 ft. per min. can be employed, this particular peripheral speed being given by the maximum spindle speed on work 17¾ in. in diameter. [*Machinery* (London), vol. 35, no. 890, Oct. 31, 1929, pp. 120–134, 13 figs., *d*]

SPECIAL MACHINERY (See also Air Machinery: A New Extraction Fan)

A Gasoline-Driven Concrete Breaker

A PORTABLE gasoline hammer suitable for concrete breaking, tamping, frost cutting, sheet driving, and other similar purposes has been developed by the Rodax Corporation, of Chicago, and is being produced in quantity lots by the LeRoi Company, West Allis, Wis.

This gasoline hammer is a portable unit, consisting of a single-cylinder two-cycle motor, with the ignition directly off a floating piston which travels in a straight up-and-down motion without connecting rod, crankshaft, or camshaft. The lower part of the piston, which is solid, strikes an anvil in which the tool cannot fall out of its socket, according to the makers. Nor can the link be lost from its hook, because it is held in place by a spring-controlled button. The speed of the hammer is from 1000 to 1100 strokes per minute.

Bolted to, and an integral part of the machine itself, is the gasoline tank. It has a capacity of two quarts of gasoline and oil, which is claimed to be enough to run the machine for $2^1/_2$ hr. The lubricating oil is mixed with the gasoline in the ratio of 6 oz. to the gallon. The spark is supplied by a hot shot battery through a small coil, connected by an insulated cable through the handle of the machine to the timer and spark plug. A button on the right handle that is accessible and convenient to the thumb connects with the cut-off switch.

There are tie-rod springs on the lower part of the machine, cushion and piston springs on the inside of it, between the anvil and the piston, which return the piston to firing position after each explosion, and a starter spring, which holds the starter in position when the machine is not in use. This starter is a plunger that extends through the top of the cylinder and starts the machine by a down pressure by hand, which depresses the piston so as to cause a charge of gas to be forced into the cylinder. The same principle applies to all two-cycle motors which take in their charges of gas, on the downward stroke, the return of the piston compressing the gas in time for the firing by means of the spark plug, when the piston is at its highest point. The entire machine weighs 87 lb. (*Traction Shop and Roadway*, vol. 2, no. 11, Nov., 1929, p. 348, 1 fig., *d*)

TESTING AND MEASUREMENTS (See also Engineering Materials: Locomotive Forgings)

The Correlation of Fatigue and Overstress

RESEARCH work in the field of phenomena of fatigue of metals has recently branched out in quite a new direction. Instead of confining the investigations to endurance determinations only, variations of fatigue limits resulting from overstress are being studied from the point of view of yield ranges. In the investigation forming the subject of the present paper two distinct series of experiments were carried out. In the one series a normal steel was overstressed (first) with symmetrical and (second) with unsymmetrical ranges of periodical stress. In the others the yield ranges of a steel which had failed in engineering practice through fatigue were investigated, and in each case after this treatment the yield ranges were studied.

The behavior of a ductile material, such as wrought iron or mild steel, when subjected to an alternating stress range of high periodicity and superimposed direct or mean stress, is very similar to that in the ordinary static test. On the addition of direct stress, while a material is subjected to a fixed alternating stress range, the relation between strains and direct stress is linear, but only for a very limited range of direct stress. With higher values a certain amount of creeping occurs, but settlement takes place in a few seconds. On further application of mean stress the amount of creeping becomes greater, until a point is reached at which the creeping becomes very great. At this point there is a definite yield, this point being the yield point. A range of stress which, when mean stress is superimposed, gives rise to yielding, is known as a "yield range."

As this mean stress may be either tensile or compressive, the corresponding yield point may be obtained. Steel supplied by the maker is in a condition termed the "primitive state," and on being tested with a range of stress and superimposed mean stress, the yield points may not necessarily occur at equal values of mean stress in tension and compression. A state, however, may be reached in which the yield points occur at equal stresses in tension and compression. This state, which is reasonably a normal state, has been termed the "cyclic state." On unloading again from these limits by varying the mean stress, the material again becomes elastic between two equal and opposite elastic limits. These limits are evidently the natural elastic limits of Bauschinger, and the material is then said to be in the "Bauschinger state."

All the work was carried out on the Smith fatigue-testing machine described in *Engineering*, vol. 88, 1909, p. 105. The method of securing the specimen is described in the paper here abstracted.

Among other things, the effect of symmetrical overstress on the yield range was investigated. By "symmetrical overstress" is meant the treatment of a material with the range of stress of which the mean stress is zero and which exceeds the greatest Wöhler range of the material. Under such conditions the specimen suffers a symmetrical yield, the position of the mid-point of the illuminated band remaining unaltered. The illuminated band is produced by the extensometer which gives a spot of light indicating the amount of strain. When a range of alternating stress acts on the specimen the spot of light appears as an illuminated band owing to persistence of vision. The amount of this yield is not usually large and the illuminated band quickly settles down to a length which remains constant so long as the range of stress continues. If permitted this range of stress breaks the specimen. Investigations of "fatigued" steel were also made.

Among other things, it has been found that freshly rolled steel is not in a cyclic state, and it is sometimes difficult to acquire this state. This may be due to the effect of the rolling strains on the molecular arrangement of the material. The effect of the stress on the specimens from the outer portion of the shaft may therefore have brought about some kind of internal rearrangement of the molecules of this fatigued steel to a more symmetrical state, and so have annulled the effect of the rolling and other strains arising from manufacture.

After a material has been overstressed by a symmetrical range of periodic stress, its stress-strain loops below the yield are closed and symmetrical. After overstress by an unsymmetrical range of stress, the stress-strain loops of a material are closed and unsymmetrical. Symmetrical overstress increases the yield ranges of a material. It is possible to obtain closed stress-strain loops with fatigued material. Fatigued material which has been stressed with practically the maximum value of stress, and is nominally overstressed with respect to the corresponding normal material, is in a cyclic state, and yields at equal values of mean stress both in tension and in compression. Fatigued material, overstressed, with respect to other fatigued material, has greater values of yield ranges, the yield-range curve in the former case falling well outside that in the latter case. Fatigue increases the yield ranges of a material. Fatigue and overstress have similar actions upon the yield ranges of a normal steel. (J. H. Smith, C. A. Connor, and F. H. Armstrong in a paper read before the Iron and Steel Institute, Sept. 12, 1929; abstracted

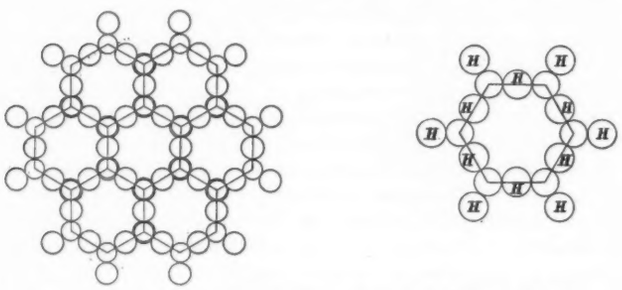
through *Engineering*, vol. 128, no. 3330 and 3331, Nov. 8 and 15, 1929, pp. 605–606, and 661–662, 24 figs., *eA*)

THERMODYNAMICS

Critical Relations Between Water and Steam

PROF. H. L. CALLENDAR in his Thomas Hawksley lecture before the Institution of Mechanical Engineers, spoke of the relations of water and steam at the critical point. In the past all the formulas in question were based on the idea that liquid and vapor are merely widely separated forms of the same condition of matter and differ only in density. The molecules in each phase were assumed to be identical, for example, H_2O, both for steam and for water, and the properties in both phases were represented by the same equation of state. Recent measurements as well as X-ray analysis have indicated that this is not so and, for example, Sir Wm. Bragg had shown by a model that throughout the whole structure each oxygen atom had for its nearest neighbors four hydrogen atoms, which were situated at the corners of a regular tetrahedron. Conversely, each hydrogen atom was directly connected to two oxygen atoms and could not be said to belong exclusively to either. There was thus no trace here of the original vapor molecule H_2O, save that the number of hydrogen atoms in the model was exactly twice as great as the number of oxygen atoms.

In view of the high latent heat of steam, it was reasonable



FIGS. 11 AND 12 NETWORK OF A SURFACE FILM OF WATER

to suppose that most of the atomic linkages occurring in ice also existed (in an incomplete state) in the liquid, though many of higher complexity must also be present. It seemed not improbable that the surface film, which was known to present special affinities to the solid phase, might consist of a complete hexagonal network, as indicated in Fig. 11. One mesh of the network was shown to an enlarged scale in Fig. 12. This network was linked by hydrogen atoms to the oxygen atoms in the layer below, as in the side view of the ice-crystal model.

On the other hand, however, both theory and experiment showed that the total heat of water could be represented by a simple thermodynamic equation which assumed that the liquid content dissolved in it, its own volume of vapor. By combining this formula with Professor Callendar's equation of state, the saturation pressure could be calculated and the results were in very close accord with observation.

The author carried a number of experiments to test the van der Waal's hypothesis that the latent heat disappeared at the critical point and the volume of the liquid became equal to that of the vapor.

In these experiments the coefficient of expansion of the liquid showed no sign of becoming infinite at the critical point, as should happen according to van der Waals, and, moreover, so far from the volume of the liquid becoming equal to that of the steam when the meniscus disappeared, the ratio was actually 3 to 5.

He had next determined the latent heat of steam at this critical point, and found it to be, not zero, as it should be according to van der Waals, but of a value of 130 B.t.u. when the meniscus vanished at 705.2 deg. fahr. In the course of this research total heats were measured for pressures up to 4000 lb. These experiments were published some time ago.

On the co-aggregation theory, both steam and water were mixtures of different kinds of complex molecules. Those in the liquid diminished with rise of temperature, while those present in the steam increased as the pressure rose. At any temperature in excess of 705.2 deg. fahr. there was no longer two distinct phases in permanent equilibrium with a sharp surface of separation, but two mixtures of different densities could, under static conditions, still be observed in the quartz tubes. Both mixtures contained the same number of active steam molecules per unit of volume, and approached identity of constitution as the active molecules were condensed by increasing pressures.

Dealing next with the question of an international steam table, Professor Callendar stated that the small outstanding discrepancy between absolute mechanical units and international electric units, which had caused so much confusion in the past, had been settled by the general admission that the international ohm was one part in 2000 larger than the true ohm. It remained to settle for steam the fundamental constants and equations involved. Some took the view that nothing should be done until every detail had been settled with the utmost accuracy, while others held that for all practical purposes there was already sufficient agreement as to the properties of steam, and that simple and rational formulas would be of the greatest assistance both to the experimentalist in his future investigations and to the engineer. There was, in fact, little prospect that all the properties of steam or indeed of any other substance, could be represented exactly by any system of equations which would not be too complicated and unwieldy for practical use. Indeed, recent researches appeared to show that there were two varieties of hydrogen, which had been provisionally named "ortho-hydrogen" and "para-hydrogen." Both were fairly stable at low temperatures, but one had a much higher specific heat than the other. The "ortho" variety could be almost completely converted into para-hydrogen by condensation on charcoal at low temperatures, and could be reconverted back again by exposure to ultra-violet light with mercury vapor as a catalyst. Otherwise the change back was comparatively slow. In view of the high proportion of hydrogen in steam it seemed not improbable that similar effects might occur. If so, they would help to explain the difficulties encountered in determining S_0, the specific heat of steam at zero pressure. Thus, observations made by a wave-length method with a frequency of 3000, appeared to give at 700 deg. fahr. a much lower value of S_0 than observations taken by a slower method, though some lag was observable even at quite moderate speeds. The best way of evading this difficulty seemed to lie in the definition of an ideal standard value of S_0 equal to $13R/3$, which was known to lead to very accurate results for the total heat of steam at low pressures and at temperatures in the neighborhood of 700 deg. fahr. (*Engineering*, vol. 128, no. 3330, Nov. 8, 1929, pp. 595–597, *tgA*)

CLASSIFICATION OF ARTICLES

Articles appearing in the Survey are classified as *c* comparative; *d* descriptive; *e* experimental; *g* general; *h* historical; *m* mathematical; *p* practical; *s* statistical; *t* theoretical. Articles of especial merit are rated *A* by the reviewer. Opinions expressed are those of the reviewer, not of the Society.

Engineering and Industrial Standardization

Standardization of Electric-Motor-Frame Dimensions

IN JULY, 1927, the American Standards Association requested the National Electric Manufacturers' Association and The American Society of Mechanical Engineers to sponsor the standardization of Electric-Motor-Frame Dimensions. This request was accepted by both organizations and a Sectional Committee consisting of 31 members representing 22 interested national organizations was formed. On March 2, 1928, the Committee held its organization meeting when W. F. Dixon was elected chairman and Lee F. Adams, secretary.

At this meeting a working committee was appointed with R. W. Owens as chairman. It held a number of meetings and recently completed the first of its proposals, that on Polyphase, Squirrel-Cage, Open-Type, General-Purpose Induction Motors for 60 Cycles at 110, 220, 440, and 550 Volts.

Electric Motor Frame Dimensions

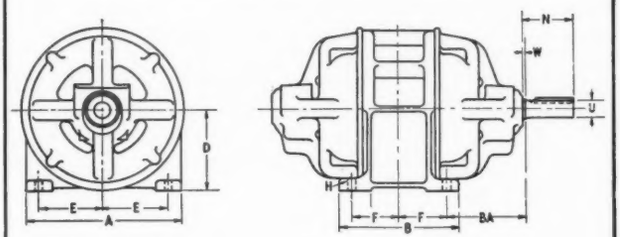


Table 1. Polyphase, Squirrel Cage, Open Type General Purpose Induction Motors for 60 Cycles at 110, 220, 440, and 550 Volts

Horse Power at 1800 rpm	Horse Power at 1200 rpm	Horse Power at 900 rpm	D	E	BA	F	H	U	N − W	Key: Width	Key: Thickness
1	¾–1	½	5	4	3½	3¼	13/32	¾	2¼	3/16	3/16
1½	1½	¾	5½	4½	3½	3⅜	13/32	1	3	¼	¼
2–3	2	1	5½	4½	3½	3¾	13/32	1	3	¼	¼
5	3	1½-2	6¼	5	4¼	4⅛	17/32	1⅛	3⅜	¼	¼
7½	5	3	7	5½	4¾	4¾	17/32	1¼	3¾	¼	¼
10	7½	5	8	6¼	5¼	5¼	21/32	1⅜	4⅛	5/16	5/16
15	10	7½	8	6¼	5¼	6	21/32	1⅜	4⅛	5/16	5/16
20	..	..	9	7	5⅞	5⅝	21/32	1⅝	5⅛	½	½
25	15	10	9	7	5⅞	6½	21/32	1⅝	5⅛	½	½
..	20	15	10	8	6¾	6⅛	13/16	2⅛	6⅛	½	½
30	25	20	10	8	6¾	6⅞	13/16	2⅛	6⅛	½	½
40	30	25	11	9	7½	7¼	13/16	2⅜	7⅛	⅝	⅝
..	40	30	11	9	7½	8¼	13/16	2⅜	7⅛	⅝	⅝
..	50	40	12½	10	8½	8	15/16	2⅝	7⅞	⅝	⅝
..	60	50	12½	10	8½	9	15/16	2⅞	8⅜	¾	¾
50	..	..	11	9	7½	8¼	13/16	2⅛	4¼	½	½
60	..	..	12½	10	8½	8	15/16	2⅛	4¼	½	½
70	..	..	12½	10	8½	9	15/16	2⅛	4¼	½	½

Dimensions in inches.

December, 1929

NEW AMERICAN STANDARDS

The following standards were approved by the A.S.A. during the month of December 15, 1929–January 15, 1930:

Standard Methods of Laboratory Sampling and Analysis of Coal and Coke. (American Standard.) Proprietary sponsor—American Society for Testing Materials. Published by the A.S.T.M.

Code for Identification of Gas-Mask Canisters. (American Recommended Practice.) Sponsored by National Safety Council. Published by the N.S.C.

This proposal was sent to the members of the Sectional Committee for approval by letter ballot, which resulted in a unanimous vote in favor. Accordingly, Chairman Dixon transmitted the proposed standard formally to the sponsor bodies on December 28, 1929.

As a step in the A.S.M.E. procedure for approval of standards it is now published for the critical review of the membership. Please address all letters to C. B. LePage, Secretary to the A.S.M.E. Standardization Committee, 29 West 39th Street, New York, N. Y.

A.S.A. Announcements

ANNOUNCEMENT that the American Standards Association has become a member-body of the International Standards Association was made at the annual meeting of the A.S.A. at the Hotel Astor, New York, on December 18, by William J. Serrill, president of the A.S.A. As the result of this action all of the national standardizing bodies except those of Great Britain, Canada, and Australia are members of the International Association. The countries now represented, in addition to the United States, are: Austria, Belgium, Czechoslovakia, Denmark, Finland, France, Germany, Holland, Hungary, Italy, Japan, Norway, Poland, Roumania, Russia, Sweden, and Switzerland.

Announcement was also made at the meeting of the reelection of Mr. Serrill as president and of Cloyd M. Chapman as vice-president for the year 1930.

The following are some of the high spots of the annual report of the American Standards Association presented by Mr. Serrill at the meeting:

1 Important progress in national standardization activities affecting most of the major American industries.

2 An agreement with the United States Bureau of Standards providing that the Bureau will promulgate commercial standards, particularly for industries having no organized standardization procedure. These standards are to be considered as preliminary rather than as broadly recognized national standards. Some of these standards will, with the approval of the proponent group, be submitted by the Bureau of Standards to the A.S.A. for approval as American standards.

3 The addition to the membership of the A.S.A. during the past year of: Laundry Owners National Association of the United States and Canada; American Home Economics Association; Tap and Die Institute; Milling Cutter Institute; and the Drill and Reamer Society.

4 Greater flexibility of A.S.A. procedure, providing four different methods under which standards can be adopted.

1929 Supplement to "Book of A.S.T.M. Standards" Available

THE American Society for Testing Materials has recently issued the 1929 Supplement to the 1927 edition of its triennial publication, "Book of A.S.T.M. Standards." The supplement contains 19 revised and 32 newly adopted standards, approved by letter ballot September 3, 1929. The standards relating to metals and those relating to non-metallic materials appear in the one pamphlet. The pamphlet is thus supplementary to both Part I, Metals, and Part II, Non-Metals, of the 1927 Book of Standards.

The Conference Table

THIS Department is intended to afford individual members of the Society an opportunity to exchange experience and information with other members. It is to be understood, however, that questions which should properly be referred to a consulting engineer will not be handled here.

Inquiries will be welcomed at Society headquarters, where they will be referred to representatives of the various Professional Divisions of the Society for consideration. Replies are solicited from all members having experience with the questions indicated. Replies should be as brief as possible. Among those who have consented to assist in this work are the following:

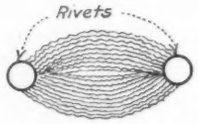
ARCHIBALD BLACK, Aeronautic Division
A. L. KIMBALL, JR., Applied Mechanics Division
H. W. BROOKS, Fuels Division
R. L. DAUGHERTY, Hydraulic Division
WM. W. MACON, Iron and Steel Division
JAMES A. HALL, Machine-Shop Practice Division
CHARLES W. BEESE, Management Division
G. E. HAGEMANN, Materials Handling Division
J. L. WALSH, National Defense Division
L. H. MORRISON, Oil and Gas Power Division
F. M. GIBSON and W. M. KEENAN, Power Division
W. R. ECKERT, Petroleum Division
MARION B. RICHARDSON, Railroad Division
WINFIELD S. HUSON, Printing Industries Division
JAMES W. COX, JR., Textile Division
WM. BRAID WHITE, Wood Industries Division

Power

Leaky Seams and Rivets in Boilers Following Use of Water Softeners

P-3 A user reports leaky seams and rivets following the use of softened feedwater. What may be the cause of this, and what remedies are suggested?

a The condition of the boiler described in the question immediately suggests caustic embrittlement as the cause. This condition frequently occurs when feedwater softeners are not judiciously used, and first indications of trouble are leaky rivets which no amount of calking can make tight. Next the seams begin to weep, and the boiler may become dangerously weakened.



After Muriatic Acid Treatment, Cracks Appear Somewhat as Indicated

To discover cracks the suspected surface of the metal should be scrubbed with a tooth brush dipped in muriatic acid. If cracks exist they will show up under this treatment. Such cracks are always of a characteristic nature, following the lines of stress in the metal, and are always found along the grain boundaries. If a case of caustic embrittlement exists, and has progressed to such an extent that the cracks are visible after the muriatic acid treatment, they usually will look somewhat as shown in the accompanying diagram.

Caustic embrittlement is caused by the use of feedwater which is too alkaline. It is suggested that those interested in this subject get a copy of the pamphlet on this subject written by Dr. Moore, and published by the University of Illinois. The writer does not believe that a boiler which has given trouble because of caustic embrittlement can be repaired satisfactorily. The obvious preventive is the use of feedwater which is not so alkaline. (Thomas J. Casey, New York, N. Y.)

b In regard to the use of softened waters, our No. 2 h.r.t. boiler, of 200 hp., which has just been opened up, has run a good deal of the time at an overload. This boiler operated on softened water and it ran under continual load day and night for 110 days. When it was opened there was nothing to remove in the way of scale, and hosing out was all that was done. So far as can be seen, there is absolutely nothing wrong with it in any way. A better-looking boiler we never saw. An inspector with his chief who happened to be present looked over the boiler, and both were well pleased. This boiler was run 110 days and was not blown either at the surface or the blow-off, but we shall blow at each shift a little, as we believe it better practice.

Use of softened water is a very important question, and one that the boiler-water compound men and water-treatment people always bring up with the caution to look out for the troubles attached to softened waters—as if we could not get into trouble with compounds if misused.

We ran for years with Dearborn treatments and had absolutely no trouble, but the continual hosing of the boilers and the going inside to clean took a day or more. If this can be done from the outside of the boiler without risks, why not do it this way? (Asa P. Hyde, Chief Engineer, Security Mutual Life Insurance Co., Binghamton, N. Y.)

c Regarding suggestions that boilers are damaged by caustic embrittlement, this being indicated by the boilers' leaking, it occurs to us that such statements may be misleading in some cases. Sweeping statements should not be made as to causes unless full information is available. Thus in one case "reddish deposits" were found, indicating corrosion. This appears to be caused by inadequate deaeration of the feedwater, and by the practice of frequent emptying and filling it with oxygen-laden water and by permitting the spare boiler to stand for long periods filled with such water. In this case there was no evidence of embrittlement. (W. J. Ryan, Technical Dept., The Permutit Co., New York, N. Y.)

Miscellaneous

Rusting of Tin Plate in Storage

M-12 What methods are used successfully to prevent rusting of tin plate in storage?

A problem at the present time occurs in connection with storing tin plate at our various factories. This tin plate is handled in bulk, that is, without being crated or boxed in any way. Packages are about $2\frac{1}{2}$ ft. square and about 14 in. high. Tin plate is shipped this way from our mill and stored in this way also until used. While in storage, especially when the weather is damp and humid, there is a great tendency for this plate to gather moisture, which causes it to rust and stain. Both of these faults are causes for rejection of the tin plate as stained plate cannot be used in the manufacture of tin cans.

After quite a good many years spent in crating this plate, bulk shipment and bulk storage were adopted. There is a considerable saving in shipping and storing tin plate in this way, also in handling it with the electric trucks, and we should not want to go back to boxing it. For this reason some scheme for conditioning the air so that it will not cause a deposit of moisture on the plate at any time during the year is needed.

Our leaning at the present time is toward a method of heating, controlling, and circulating the air at considerable velocity through these departments in the hope that it may pick up the moisture and prevent its deposit on the plate. Whatever scheme we should adopt would have to be applicable to the walls also, as a good deal of this plate is stored in concrete buildings, and we find that these concrete walls condense moisture very readily on humid days. (J. L. Kirsch, General Plant Engineer, Continental Can Co., Inc., Chicago, Ill.)

Questions to Which Answers Are Solicited

Bending a Heavy I-Beam

M-3 It is proposed to bend a 9-in. I-beam of heavy section to a radius of 11 ft. 3 in. What methods are recommended to accomplish this without destroying the shape of the web of the beam?

Conveying Sand Hydraulically

M-10 It is planned to convey sand from a washer to a height of 20 ft. above the washer by means of water injected at high velocity through a nozzle into a 5-in. pipe. Does this arrangement seem feasible, or will the quantity of water to be disposed of offset the advantages gained by the elimination of mechanical apparatus?

Etching Numbers on Thickness Gages

M-13 What is an inexpensive method of etching numbers on thickness gages? A rubber stamp dipped in acid has been tried, but with acid strong enough to etch the impression clearly, the rubber stamp is corroded.

Causes and Remedies for Cinder Cuts in Boiler Flues of Locomotives

R-4 What are the causes and satisfactory remedies for cinder cuts in the flues of steam locomotives? They occur both inside the firebox above the firebricks at the boiler head and also in the front end or smokebox.

Counterbalancing Freight Locomotives

R-5 The counterbalance of a heavy freight engine, class L2, has been found 390 lb. too light. The only place where more weight can be added is at the ends of the counterbalance and close to the center of the wheel. How can the required weight be calculated?

Developments in Long-Draft Spinning of Cotton Yarn

T-2 What are the latest developments in long-draft spinning of cotton yarn? Has any system of long-draft spinning been generally adopted in this country?

Treating Wood for Use in Lining Refrigerator Cooling Rooms

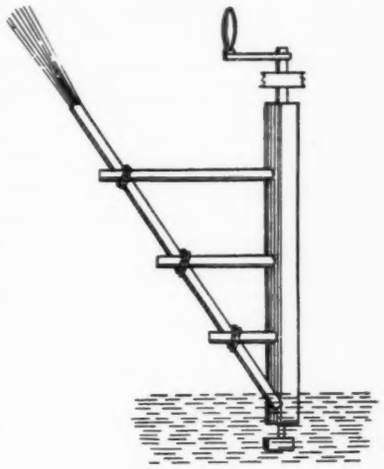
WI-4 Coniferous, odorless woods are used as linings of refrigerator cooling rooms. How can these woods be impregnated in such a manner as to keep them from absorbing moisture and at the same time not impart an odor or other undesirable condition?

Correspondence

Joseph's Well

To the Editor:

Referring to the comments on Joseph's Well at Cairo in the very interesting article on "The Development of the Deepwell Turbine Pump," by W. H. Holcomb, in the November issue of Mechanical Engineering, it may be worth while recording that there is a fairly full description of this well in "Hydraulics and Mechanics," written by the American author, Thomas Ewbank, in 1841. So far as I have been able to trace, there is no definite evidence as to when the well was constructed, but it is clearly of very ancient origin.



Le Demour's Pump
(From Ewbank's "Hydraulics," p. 230.)

Ewbank also describes and illustrates what appears to have been the first centrifugal pump. A copy of his illustration is submitted herewith. This pump was invented by M. Le Demour in 1732, and was merely a straight tube attached in an inclined position to a vertical axis, and whirled around by a handle. The tube was fastened by ligatures to three strips of wood projecting from the axis.

Hugh P. Vowles.[1]

Load and Stress Cycles in Gear Teeth

To the Editor:

In the paper "Load and Stress Cycles in Gear Teeth," by R. V. Baud and R. E. Peterson, published in the September issue of Mechanical Engineering, Equations [6], [7], and [8] should be revised to read as follows:

$$d_g = (d_2)_g \frac{\cos^2 \alpha_g}{\cos \phi} \left(\frac{Y_2}{Y_1} \right) \quad [6]$$

$$d_p = (d_2)_p \frac{\cos^2 \alpha_p}{\cos \phi} \left(\frac{y_2}{y_1} \right) \quad [7]$$

$$c = \frac{d_1}{\cos \phi} \quad [8]$$

Dimensions Y_1 and Y_2 refer to the gear.

These revisions do not alter greatly the final results, but are given here because they are simpler and more accurate than the equations given in the paper.

R. E. Peterson.[2]

East Pittsburgh, Pa.

[1] 20 Ridgway Place, Wimbledon Common, London, S.W. 19. Mem. A.S.M.E.

[2] Research Laboratory, Westinghouse Elec. & Mfg. Co., Assoc. Mem. A.S.M.E.

MECHANICAL ENGINEERING

A Monthly Journal Containing a Review of Progress and Attainments in Mechanical Engineering and Related Fields, The Engineering Index (of current engineering literature), together with a Summary of the Activities, Papers, and Proceedings of

The American Society of Mechanical Engineers

29 West 39th Street, New York

CHARLES PIEZ, *President*

ERIK OBERG, *Treasurer* CALVIN W. RICE, *Secretary*

COMMITTEE ON PUBLICATIONS:

W. A. SHOUDY, *Chairman* F. V. LARKIN

W. H. WINTERROWD L. C. MORROW

S. F. VOORHEES

C. E. DAVIES, *Secretary to Publications Committee*

PUBLICATION STAFF:

G. A. STETSON, *Editor*

FREDERICK LASK, *Advertising Manager*

Contributions of interest to the profession are solicited. Communications should be addressed to the Editor.

BY-LAW: The Society shall not be responsible for statements or opinions advanced in papers or . . . . printed in its publications (B2, Par. 3).

Revised Index Classifications

READERS of MECHANICAL ENGINEERING will receive with interest the announcement that The Engineering Index Service has undertaken a thorough revision of the classifications under which it issues its card service, and has reduced its rates in many cases.

The venture with the Index was a pioneering one. To publish daily more than two hundred cards containing references to the vast variety of engineering literature which is received by the Engineering Societies Library is in itself no small accomplishment. To insure that the best use is made of these cards and that they are so carefully classified that any person may select groupings of subjects with the assurance that his needs are to be served and that he misses nothing, requires knowledge born of experience as well as intelligent preplanning. Two years' experience has laid the foundation for the new classifications that have been announced in the printed circulars distributed by the Index Service. Experience has also provided a sound basis for estimating the probable number of cards which may be expected in a given class, and hence has made possible a revision of rates for the service.

No one has ever explored completely the possibilities for usefulness and value which the Engineering Index Service possesses. It is a pioneering effort, and hence only its most obvious uses are developed. Subscribers to the Service are making applications of it in their professional and commercial interests which give to it the larger significance that its sponsor, the A.S.M.E., has always visualized. The new classification should do much toward enhancing the usefulness and extending the scope of this important service.

Speeding Up Automobile Traffic

IN THE last two years a tremendous effort has been made on all sides to speed up automobile traffic. This, of course, has been done most effectively by laying out new roads or by improving older roads—for example, by the elimination of grade crossings. One of the methods of achieving the same end, however, has been the passing of legislation which permits fast travel over common highways and even side streets, ranging from 35 miles on highways to such fantastic rates as 70 miles in certain sparsely populated counties of the state of Texas. The presumption was that a skilled driver is safe to himself and others even when traveling at a high speed, and that an unskilled driver is unsafe at any speed. Figures so far have failed to justify this assumption. Within the past year the number of automobile accidents has increased much faster than the number of automobiles, and observation of city and county authorities in many places would indicate that increased speed has a lot to do with this growth of accidents, particularly in states where there are no examinations for drivers or where these examinations are lax or are apt to be a mere formality for people of standing in the community or those who have political connections.

It is very difficult to believe that we shall go back to the lower speeds, no matter how many accidents occur. The spirit of the age is go faster and faster, but it is well to recognize that until some radical changes in our traffic arrangements are made, this increased speed will be paid for in human lives and misery. It is well to recognize frankly, at times brutally, the price that we pay for the mechanization of our life.

Popularization of Science

THERE is ample evidence that success is being achieved in the popularization of science. Only recently, in New York City, a riot resulted when a vast crowd of persons whose curiosity had been aroused by the reading of press accounts of Einstein's contributions to science found itself too numerous to view a film demonstrating the famous theory which so few are reported to understand. The "monkey" trial in Tennessee not so many years ago, the reports of archeological researches in Egypt and Chaldea, the finding of anthropological remains, accounts in the press of the meeting of the American Association for the Advancement of Science, and abstracts of the papers there presented, the great amount of aeronautical news—all these are evidence of the fact that there is great popular interest in science, pure and applied.

The reasons are not far to seek. Civilization today is based upon science, so that many of the facts of science are well known and stimulate interest in the theories. Education, much more widespread than ever before, has broadened to include a study of the fundamental sciences, even in the primary grades, while the number of persons educated in secondary schools and colleges is steadily on the increase. Industrial and academic laboratories are developing almost daily spectacular and important scientific truths which bear closely upon our lives and environment. These become news; whereupon the press accepts and publishes them.

Our interests in science are becoming personal. Tomorrow's discovery may wipe out an industry established over many years, and at the same time set up a new one in which there will be countless opportunities. We must keep abreast of scientific knowledge, or build blindly and foolishly.

Engineers and scientists have everything to gain in the popularization of science. They should welcome and assist all attempts at interpreting their special knowledge to the world at large.

The Railroad-Merger Plan of The Interstate Commerce Commission

THE plan for railroad mergers given out by the Interstate Commerce Commission last December is the second one to be offered, the first having been worked out by Prof. W. Z. Ripley some ten years ago. The Esch-Cummins Transportation Act makes it incumbent upon the Interstate Commerce Commission to work out such a plan, and the Commission accordingly has done so. The value of such a plan, however, must not be overrated, because in the first place it is not binding even on the Interstate Commerce Commission itself, as the law gives that body the right to modify the plan whenever in its judgment this is necessary; and it is in accordance with this provision of the law that the initial Ripley plan was abandoned and the present plan worked out.

In the next place, it must be clearly realized that the Interstate Commerce Commission has the right to reject any plan submitted to it, but has no powers to impose on any one the plan that it has devised. Of course, if the Commission were to make it plain that it would accept no other plan, it would then be up to the railroads to work along the lines laid down by the Commission if they wanted mergers. Which plan would be preferred it is difficult to say, and most likely the whole merger movement would be delayed for years. It is important, however, to note that the Interstate Commerce Commission has taken full cognizance of the groupings in the transportation field already effected in skeleton outline, in particular, through certain holding companies. In the past the Interstate Commerce Commission has taken the view that railroads should not obtain control of lines which they desire to merge without previous approval of the Commission. On the other hand, it is obvious that the railroads should first obtain the approval of the Commission to effect a merger, and then go into the market and buy the securities of the lines to be merged. At the worst a highly inflated price would have to be paid for these securities. Those interested in effecting mergers have resorted to the device of creating holding companies not subject to the control of the Interstate Commerce Commission and capable of accumulating stocks of lines which they intend to merge. The most prominent examples of such holding companies which suggest themselves are the Alleghany Corporation, controlled by the Van Sweringen and Morgan interests, and the Pennroad Corporation, organized in the interests of the Pennsylvania Railroad.

The present plan of the Interstate Commerce Commission does not exactly coincide with any of the merger plans worked out by private interests. Taking, however, the eastern territory, it will be noticed that there is a good deal of similarity between the groupings suggested by the Commission and those proposed by the Chesapeake & Ohio and the Baltimore & Ohio. There is therefore reason to believe that at least these two groups may see fit to sacrifice, perhaps for the time being, their more ambitious plans and to accept in its entirety, or very nearly so, the scheme which the Commission has indicated as permissible. Should this happen, the other roads will be constrained to work out their plans around the fixed and—by that time—immutable structure of the completed mergers. In other words, the plan of the Interstate Commerce Commission would seem to be to have a certain number of key roads, around which the others would be left to group.

From the point of view of mechanical engineers, the railroad mergers are of interest in two ways. They may cost jobs to some of them through the concentration of engineering departments and the elimination of present duplications. On the other hand, the increase in efficiency which may be reasonably looked for as a result of the mergers will place in the hands of the merged companies increased funds, and these will be spent in various improvements and thus create more work. Finally, engineers as a whole are interested in the improvement of transportation generally, and there is very little reason to doubt that such an improvement will be brought about by intelligently planned mergers.

Fred R. Low Becomes Editor Emeritus of "Power"

THE publishers of *Power* have announced the retirement from active editorial service of Fred R. Low, since 1888 editor of that important and well-known technical journal. Mr. Low becomes editor emeritus, thus advancing to a position which affords him the well-earned rest from active affairs to which his long and faithful service has entitled him. His friends and readers, who constitute a majority of the engineers of this country, cannot begrudge Mr. Low this reward for distinctive accomplishments, much as they may regret the fact that his vigorous leadership will no longer guide the policy of the paper he has made famous. There is solace in the assurance which Mr. Low himself gives in his "Valedictory" that the signed editorials which have for so long been the initial feature of *Power* are to continue to come from his pen.

Mr. Low's services to engineering and to the A.S.M.E. are familiar to readers of MECHANICAL ENGINEERING. The Society's editors have learned to look to Mr. Low for counsel and guidance, and his innumerable services are gratefully acknowledged. His presence at the Society's headquarters, due to his active participation in professional affairs, has brought him into close personal contact with members of the staff. Between his sojourns in the South during the winter and in New England during the summer it is hoped that he will find an opportunity to visit the scene of so many of his activities of past years. As a member of numerous important committees, as an honored past-president, and as a friend and well-wisher of the Society, Mr. Low will continue to serve the great army of engineers who bear for him such warm and sincere affection.

Coincident with the announcement of Fred Low's retirement comes that of the appointment as editor of *Power* of Ely C. Hutchinson, member of the Council of the A.S.M.E. While Mr. Hutchinson has spent much of his professional career on the Pacific Coast, he is no stranger to eastern members of the Society. He was active in the formations of the Society's Professional Division on Hydraulics, and was the first chairman of this Division and is still a member of its executive committee. He was elected a manager of the Society in 1928. He is a member of the Hydraulic Power Test Code Committee of the A.S.M.E. and of the Engineering Societies Library Board.

A notable career in engineering has fitted Mr. Hutchinson for the responsible position which he assumes as editor of *Power*. A wide acquaintanceship among engineers from coast to coast and a thorough knowledge of the field which his valuable paper represents, augment a charming personality and vigorous leadership.

Mr. Hutchinson falls heir to a position which his distinguished predecessor has made notable, and to a staff of editors who are favorably known and capable. The close and cordial relations which these men, under the leadership of Fred Low, have maintained with the Society and with MECHANICAL ENGINEERING should continue to develop even greater opportunities for cooperation in the service of engineering under Mr. Hutchinson's editorship. The publishers of *Power*, its board of editors, its readers, and the engineering profession are to be congratulated upon the appointment of Mr. Hutchinson, as is also he upon the opportunity which lies before him.

Wilfred Lewis
1854–1929

WILFRED LEWIS, retired president of the Tabor Manufacturing Company, and for forty years an expert in gears, died at sea on December 19, 1929. He was returning from Tokyo and was buried at sea near Egypt from the steamship *President Wilson*. Mrs. Lewis was traveling with him.

Wilfred Lewis was born in Philadelphia, Pa., October 16, 1854. He was the son of Edward and Elizabeth I. Lewis. His education was received at the Friends' Central School, Philadelphia, and at the Massachusetts Institute of Technology, from which he was graduated in 1875 with the degree of B.S. in mechanical engineering.

Serving as a mechanic from 1875 to 1878, and as a draftsman from 1879 to 1882, he became successively designer, assistant engineer, and director of William Sellers and Company, Philadelphia, from 1883 to 1900. In 1900 he was made president of the Tabor Manufacturing Company, in Philadelphia, a position which he held until his retirement from active service about a year ago.

Mr. Lewis was a productive inventor. He was an expert in the design, construction, and testing of gears. His interest in this subject, which commenced when he was employed by William Sellers and Company, brought forth a paper on "Experiments on the Transmission of Power by Gearing," published in the Society's Transactions in 1886. Later, in 1910, at a joint meeting of the A.S.M.E. and the I.M.E. held in Birmingham, England, he described the first machine he had built to determine the friction loss of gears under various speeds and pressures. This machine was set up and run at the Massachusetts Institute of Technology. In the Transactions of 1918, in discussing a paper on the efficiency of gear drives, he described his second machine, built for use at the University of Illinois. His third machine, described in the December, 1922, issue of MECHANICAL ENGINEERING, was built for the Special Research Committee on the Strength of Gear Teeth, of which he was chairman, and is being used by the committee at the Massachusetts Institute of Technology in the investigation it is carrying on to determine the effect of tooth accuracy on the strength of gear teeth at varying velocities.

WILFRED LEWIS

Because of his valuable contributions to engineering in the field of gearing, Mr. Lewis was awarded the A.S.M.E. Medal in 1927. In presenting him as the recipient of the award, Conrad N. Lauer said:

"This man is a world authority on gears. His formula, the universal guide in gear design, is the result of abstract analysis rather than of elaborate experimental tests. He was the first specialist to eliminate the rule of thumb in gear design and to place it on a sound engineering basis."

During the war Mr. Lewis served at Washington as an adviser in the development of fighting tanks.

Mr. Lewis joined The American Society of Mechanical Engineers in 1884. He was a life member of the Society, and served as vice-president from 1901 to 1903. He was a member of The Franklin Institute, and in 1927 received its Longstreth Medal for perfecting a molding machine.

He was a member of the Philadelphia Art Club, the Merion Cricket Club, the Engineers' Clubs of Philadelphia and New York, and the Historical Society of Pennsylvania.

On January 16, 1895, Mr. Lewis married Emily Sargent, who, with his sons Leicester and Wilfred S. Lewis, and a daughter. Mrs. Horace Pettit, Jr., survives him.

Sherwood F. Jeter
1872–1929

SHERWOOD FRANK JETER, vice-president of the Hartford Steam Boiler Inspection and Insurance Company, died suddenly on December 31, 1929, at the Hartford (Conn.) hospital following an operation from which he had apparently been recovering.

SHERWOOD F. JETER

Mr. Jeter was born in Columbus, Ga., December 5, 1872, the son of Francis Marion Jeter and Julia Lindsay.

He was graduated from the Georgia School of Technology, Atlanta, Ga., in 1893 with the degree of B.S. in mechanical engineering. He then entered the electrical engineering field in lighting, power, and street-railway work, and spent a year in Mexico City as an electrician for the Mexican Telephone Co.

In 1898 Mr. Jeter became a boiler inspector for the New Orleans department of the Hartford Steam Boiler Inspection and Insurance Company. He remained with this company in its New Orleans, Pittsburgh, and Hartford offices until 1906, with the exception of nine months when he reentered the street-railway field as master mechanic of the Pittsburgh, McKeesport, and Connellsville Railway Co. at Connellsville, Pa.

In 1906 he became mechanical engineer for the Bigelow Company, manufacturers of boilers at New Haven, Conn. While with this company he redesigned the Hornsby water-tube boiler to meet the manufacturing and operating conditions in the United States.

During the latter part of 1910 Mr. Jeter returned to the Hartford Steam Boiler Inspection and Insurance Company as supervising inspector. In 1915 he was made chief engineer, and in 1927 he took over all of the company's engineering activities as vice-president.

Mr. Jeter joined the A.S.M.E. in 1909 and has been active in the work of the Boiler Code Committee since 1913, being a member of that committee and its executive committee. In 1917 he undertook the organization of the Hartford Branch of the Connecticut State Section, now the Hartford Local Section of the Society, and served as its chairman in 1920–1921. He was a manager of the Society from 1921 to 1924, and vice-president from 1924 to 1926.

Mr. Jeter married Alice Gamard, on August 29, 1900, who survives him, as do his five children, Mrs. Frank E. Wolcott, Sherwood Frank, Jr., Helen, Alfred, and Lindsay.

The New York Automobile Show

FROM a strictly engineering point of view the New York automobile show of 1930 was, if not disappointing, at least dull. There was scarcely a novel thing shown in the way of larger mechanical improvement, which in a way is not surprising if we bear in mind the very high state of perfection which the modern gasoline automobile has reached. The past history of engineering progress has shown that when this happens there is a short lull, followed by a ruthless scrapping of the machine which looked so admirable, and its replacement by something entirely different but vastly better. At the Centennial Exhibition in Philadelphia in 1876 the public stood in awe in front of the five-thousand-horsepower Corliss engine, wondering if anything more powerful would ever be built, and at that very time an English inventor was putting the final touches on his idea of a steam turbine, which type of motive power has now relegated the engine to a secondary place for large power outputs.

Just what revolutionary changes will occur in the design of the modern automobile, no one knows of course today, but those who think they do, tell it to the Patent Office and not to the public. However, several possible tendencies are becoming apparent. In the first place, there is the ever-present experimenter with the Diesel engine. The difficulties in the way of producing a Diesel engine as flexible as the modern gasoline automobile engine are tremendous, but the possibility of substituting engine oil for gasoline and thus cutting the cost of fuel in three or four is so fascinating that more and more engineers are devoting their attention to the problem. Quite recently an automobile (invented by a Mr. Cummings of Indianapolis) was driven several hundred miles under Diesel power, and this, coming on top of the apparent success of the Packard Diesel engine for aircraft, is significant.

Four-Wheel Drive

The introduction of front-wheel drive by Cord and Ruxton points to the possibility of a car with four-wheel drive; this may be expensive to build, but it will be extremely handy for city traffic, parking, and driving through sandy and difficult ground. The mechanical problems involved, now that the problem of driving through the front wheels has been solved, are not great, and the question is primarily one of added cost and complication of apparatus.

If, however, four-wheel drive is adopted, there is no further advantage in keeping the engine in front, which is merely a survival from the days when it had to be easily accessible for repair and adjustment purposes. The modern high-grade engine does not need to be looked after except at times of general overhaul, and may therefore be placed anywhere. The best location for it is of course in the rear, with a rack for spare tires and luggage over the hood, which will make the car shorter and give it somewhat the appearance of an electric. This would at once solve the great saturation problem by making every automobile now in existence look like that least pleasing of possessions, an outmoded car.

A number of cars are now provided with radio receiving sets, and the introduction of this feature required some rather remarkable engineering on the part of the radio men to produce condensers and tubes that would stand the jolting encountered in an ordinary automobile.

Engineers are naturally interested in the economic as well as the mechanical aspects of an industry as important as the manufacture of automobiles has become, and an economic analysis of what the New York Show had to offer leaves one with a somewhat uneasy feeling.

Statistics show that there is one automobile to every five persons in the United States, one bicycle to every five in France, and one pair of shoes to every five in Soviet Russia. This is as it should be, considering the relative wealth of the countries named, but is it really necessary that the "one automobile to every five persons" in the United States should be an eight-cylinder car? As long as the eight-cylinder car was built for the well-to-do, there was an ample justification for its manufacture. For a heavy car an eight-cylinder engine is of material advantage, and gives a performance which cannot be obtained with a six-cylinder engine of the same weight and dimensions. For a smaller car, however, the performance of the modern six-cylinder engine is so good that there does not seem to be any special reason for going to eight cylinders, as the improvement from the use of the latter (and no one will deny that there is an improvement) is obtained at an additional cost which really only a wealthy person should be willing to assume.

Economic Aspects

While the wealth of this country is growing greater and greater and the national income will shortly require twelve figures for its expression, there is a limit somewhere to what ought to be spent for luxuries and for those articles in which utility and luxury merge. A four-cylinder automobile may be considered primarily a utility; in the six-cylinder, utility and luxury meet; the eight-cylinder car, however, is a luxury pure and simple, even for a country as rich as the United States—and twenty-two different makes of eight-cylinder cars are now under construction in this country.

There is already a very interesting repercussion to this situation. The general public has taken to the eight-cylinder car, but there is a limited class who must have something more expensive, and a sixteen-cylinder job is offered to them by the Cadillac Company, which is a wise thing to have done, as otherwise those who will now use the Cadillac-16 would have bought foreign cars.

Within the last two years the four-cylinder car has been abandoned by all save the Ford Motor Company. Twenty-two makers have gone over to the eight, the majority of them within the last twelve months. Does this mean that the day is coming when we shall have the four-cylinder Ford and eights only? It is a pleasure to drive an eight-cylinder car, but what about eight-cylinder bills for gasoline, oil, and repairs?

While somewhat doubtful as to the national wisdom of changing from the six to the eight, there will be universal agreement as to the wonderful performance of American engineering and tool-making that has made it possible to produce an eight-cylinder car selling for $1000 or sometimes for even less. In this connection engineers will be interested in following the fortunes of the Austin Motor Car Company, a prominent English builder of medium-priced cars, which has lately invaded the American market and has a plant at Butler, Pa. Another British company, the Rolls-Royce, some years ago started to build cars in the United States, but it catered only to the wealthiest, for whom cost is not a controlling factor. The Austin Company, on the other hand, is appealing to people who want a car but are not going to pay an extra hundred dollars for the glory of driving a machine with a foreign-sounding name. If, as every one hopes, the company makes a success in America, it will be interesting to see how the number of hours per car and the manufacturing cost of the car in dollars and cents in this country compare with the figures in England—interesting not only for the English, but still more so for American engineers.

Book Reviews and Library Notes

THE Library is a cooperative activity of the A.S.C.E., the A.I.M.E., the A.S.M.E., and the A.I.E.E. It is administered by the United Engineering Society as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West 39th St., New York, N. Y. In order to place its resources at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references on engineering subjects, copies of translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

Scientific Management in American Industry

SCIENTIFIC MANAGEMENT IN AMERICAN INDUSTRY. By The Taylor Society. Harper & Brothers, New York, 1929. Cloth, 6 × 9¼ in., 479 pp., illus., $6.

REVIEWED BY L. P. ALFORD[1]

THIS book, sponsored by the Taylor Society and prepared under the editorship of H. S. Person, its secretary, is a major addition to the interpretative literature of scientific management. Henry P. Kendall in the foreword says of it: "This book is a summary of a decade's study, analysis, and exposition of the philosophy, principles, and procedures of scientific management; and a picture of its status and influence today." It deals with the expansion of the influence of the life and work of Frederick W. Taylor, which is summed up in the preface thus: "But the fact that he instilled a priceless optimism into industry, and therefore into life, constitutes . . . . his chief claim to our gratitude." Another paragraph gives this reason for producing the book: "And so, to pass on not a finished product but a vibrant, growing, exhilarating industrial practice for development and refinement in our throbbing present-day experience, is the object of this book."

Thus the ideal for this book has been set at a high level, and its plan and scope on a most comprehensive plane. Both purpose and objective are reasonably attained.

The volume is made up of a series of twenty-nine monographs contributed by twenty-six authors, including the editor. They are divided into six parts: Introduction; Management Research; Management Standards; Control of Operations; Maintenance of Standards; Human Aspects. As might be expected, the treatment adopted by the various authors is far from uniform. The volume therefore has the common characteristic of a symposium, a lack of free-flowing thought and presentation, because of the difference in viewpoint, attack, and method of the several contributors. Some chapters pay little attention to current practice—XVII, on the use of standards, serves as an example. Others, and among these are some of the best, have been developed upon the firm basis of practical applications—XI, Administrative Standards; XV, Factory Operating Standards; XXIV, Inspection of Performance; fall in this group. A few are but descriptions of a management case or installation—VI, Research for Clerical Operations is one.

The decade-old difficulty of reconciling Taylor's four principles of management with the development of management practice is squarely met by Dr. Person in the first chapter. His own presentation of the Taylor principles in "arrangement and emphasis to answer the dominant questions of 1929" is well worthy of quotation:

1 Research, investigation, and experiment constitute the only sound basis for the solution of managerial problems. . . .
2 To make them useful to an enterprise the results of research, investigation, and experiment must be made available to the cooperating group in the form of defined and published standards. . . .
3 There must be established a systematic procedure, based on the defined standards, for the execution of work. . . .
4 Durably effective management requires recognition of the natural laws of cooperation. . . .

It is interesting to discover conflicting testimony as to Taylor's appreciation of the human element in industry, and this fact emphasizes the impartial spirit in which this book has been planned and carried through. Robert W. Bruère, in the chapter on Industrial Relations, says: "As to shop conditions, for example, there is no word in Taylor's writings about the need for making the workshop a fit and pleasant place for men to work in. In his 'On the Art of Cutting Metals' he lists as one of his discoveries the high advantage of supplying water to cutting tools. Nowhere in Taylor's writings is there any reference to that whole range of problems which is concerned with supplying the workers with safety, or cleanliness, or good lighting, or any of the things which come within scope of industrial hygiene. Because of his preoccupation with the mechanical equipment, Taylor inevitably thought of the workman almost exclusively in terms of skill, application, and production, rather than in terms of personality." Dr. Person in his opening chapter writes: "Those who, reacting to the development of scientific method during recent decades, . . . even in special fields such as employer-employee relations . . . have found themselves developing techniques and expressing philosophies essentially identical with the technique and philosophy expressed by Taylor nearly half a century ago."

In the second chapter are frequent references to the laws of management: "...the essence of scientific management is substitution of the laws of the situation for arbitrary authority." In spite of this setting the authors of the later sections have done but little to give us renewed statements and interpretations of the fundamentals of scientific management. This fact may be looked upon as the most regrettable lack in a very worthwhile presentation.

[1] Vice-President, The Ronald Press Company, New York, N. Y. Mem. A.S.M.E.

Turning back to the evaluation in the opening paragraph of the present review, this volume, sponsored by The Taylor Society, is a distinct contribution to the interpretative literature of scientific management. It deserves a place in the library of any one who has to do with the science, art, or practice of getting work done.

Books Received in the Library

AIRCRAFT HANDBOOK. By Fred H. and Henry F. Colvin. Fourth edition. McGraw-Hill Book Co., New York, 1929. Fabrikoid, 5 × 8 in., 690 pp., illus., diagrams, tables, $5.

As indicated by the title, this book summarizes in convenient form much information on the construction and operation of aircraft, and on the aviation industry in general. Current types of planes and engines are described; advice is given on rigging and servicing, airport construction, and on similar matters. The book has been revised; obsolete matter has been eliminated and new developments noted.

APPLIED AERIAL PHOTOGRAPHY. By Ashley C. McKinley. John Wiley & Sons, New York, 1929. Cloth, 6 × 9 in., 341 pp., illus., diagrams, $5.

This book, by the aerial surveyor of the Byrd Antarctic Expedition, aims to make available in one work a compact study of modern aerial photography. The instruments used, the taking and finishing of photographs are described, and the methods of mapping with or from photographs are explained. A chapter is devoted to the method of oblique aerial mapping developed by the Surveys Bureau of Canada. A practical working knowledge of cameras, photographic emulsions, and processes of photographing is presented.

ATLAS METALLOGRAPHICUS. Lief. 3–5; Tafel 17–40. By Hanemann & Schrader. Gebrüder Borntraeger, Berlin, 1929. Paper portfolio, 8 × 11 in., 3 parts, plates, part 3, 6.60 r.m.; pts. 4 and 5, 6.75 r.m. each.

These three new sections of this useful atlas contain 143 photomicrographs of the structure of steel after various heat treatments. The photography is good and the structures are clearly shown. A clear description accompanies each plate.

BLAST FURNACE PRACTICE, Vol. 3: Operation and Products. By Fred Clements. Ernest Benn, London, 1929. Cloth, 8 × 10 in., 400 pp., illus., diagrams, tables, 63 s.

The concluding volume of this great treatise discusses the operation of the blast furnace and the utilization of its by-products. The calculation of the burden, the control of the temperature and physical condition of the furnace, and the methods of blowing in, damping, and blowing out are discussed, as well as the solution of such operating problems as break-outs, scaffolding, hanging, and chilled hearths. A chapter is devoted to safety and hygiene. Labor economics, operating records, and costs are discussed. The cleaning and utilization of gas, the recovery and treatment of flue dust, and the utilization of slag are described. The last two chapters discuss briefly ferromanganese and other ferroalloys, and the production of charcoal and electric pig iron.

No other book covers the entire field of blast-furnace practice so comprehensively and practically. Every operator, designer, and engineer will find the book of interest. The abundant illustrations and drawings add much to its value.

BUSINESS REPORTS; Investigation and Presentation. By Alta Gwinn Saunders and Chester Reed Anderson. McGraw-Hill Book Co., New York, 1929. Cloth, 6 × 9 in., 411 pp., $3.50.

The first part of this book describes the steps in investigating a business: the analysis of the problem, the preparation of a plan of work, the collection and recording of the data and its analysis and interpretation. In the second part which is the main concern of the book, the principles of presenting information in written form are given, as well as advice on procedure which will secure the reading of reports and acceptance of their recommendations.

LE CALCUL VECTORIEL. By Raoul Bricard. Armand Colin, Paris, 1929. Paper 5 × 7 in., 199 pp., 10.50 fr.

A concise, clear, elementary text setting forth the principles of vector analysis and discussing the applications of the method to geometry, mechanics, and electricity.

CITY PLANNING....edited by John Nolen. Second edition. D. Appleton & Co., New York and London, 1929. Cloth 5 × 8 in., 513 pp., illus., maps, plans, $3.50.

A carefully related series of essays by sixteen authorities which, taken together, cover the essential elements of a city plan. The problems that confront practically all cities and towns are dealt with, and the best practice in investigation, planning and control is discussed in readable form for the interested public. This edition contains new chapters on zoning and regional planning.

CONTRIBUTION A LA THÉORIE DE L'HÉLICE PROPULSIVE. By Maurice Roy. (Aéro-Club de France. Travaux du Cercle d'Etudes Aérotechniques. Fascicule 3.) Le Centre de Documentation Aéronautique Internationale de l'Aéro-Club de France, Paris, 1929. Paper, 8 × 10 in., 38 pp., diagrams, tables.

A mathematical investigation of theories of the screw propeller, with special reference to the airscrew. Particularly the author discusses the conceptions developed by Rankine and Froude concerning the ideal screw, and points out certain modifications and corrections that are necessary.

EINFLUSS DER VERUNREINIGUNGEN IM SAUERSTOFF UND IM AZETYLEN AUF DIE WIRTSCHAFTLICHKEIT UND GÜTE DES SCHNITTES UND DER SCHWEISSNAHT. By W. Rimarski, C. Kantner, and E. Streb (Forschungsarbeiten....heft 317). V.D.I. Verlag, Berlin, 1929. Paper, 9 × 12 in., 44 pp., illus., diagram, tables, 6 r.m.

Reports the methods used and the conclusions reached in an extensive laboratory investigation. Both hand and machine welding were investigated. The effect of impurities upon speed and quality was determined.

ENGINEERING MECHANICS, Part 1: Simple Statics, Dynamics of Translatory Motion, Dynamics of Rotatory Motion. By William S. Franklin and Zenas R. Bliss. Franklin & Charles, Lancaster, Pa., 1929. Cloth, 6 × 9 in., 287 pp., diagrams, tables, $2.75.

A textbook for engineering students, based especially on the views of Kelvin, Tait, and Rayleigh. The book aims to focus attention on the more fundamental aspects of the subject, and to omit much that is not really fundamental.

EVOLVENTEN-STIRNRADGETRIEBE. By R. Herrmann. Julius Springer, Berlin, 1929. Paper, 7 × 10 in., 112 pp., illus., diagrams, tables, 9.60 r.m.

A practical guide for designers and makers of involute spur gearing. The author discusses the calculation of the best proportions, the processes and tools for cutting gears, and methods of testing and measuring. Tables give the necessary data for all sizes ordinarily used.

GAS AIR-LIFT POCKET BOOK. By Robert Stirling. E. & F. N. Spon, London; Spon & Chamberlain, New York, 1929. Fabrikoid, 5 × 7 in., 95 pp., diagrams, tables, 5 s.

This little book calls attention to the possibilities of the air-lift method, first applied in Baku during 1900, for pumping oil wells. The theory and working of the air-lift and its application to oil

wells are described briefly, yet with sufficient detail for the practical engineer.

GAS ANALYSIS. By L. M. Dennis and M. L. Nichols. Revised edition. Macmillan Company, New York, 1929. Cloth, 5 × 8 in., 499 pp., diagrams, tables, $4.

Dennis' "Gas Analysis" has long been an accepted authority, and the new revision, the first in sixteen years, brings in the important advances during this interval. Among the new topics are methods of analysis based upon thermal conductivity, new procedures for determining specific gravity, the interferometer and its use, and a discussion of specific absorption and of the correction of barometric readings. The book covers the subject comprehensively.

INDUSTRIAL FURNACE TECHNIQUE. By A. Hermansen. Ernest Benn, Ltd., London, 1929. Cloth, 6 × 9 in., 293 pp., illus., diagrams, tables, 25s.

The author of this book, a well-known Swedish designer and manufacturer of industrial furnaces, has long been engaged in developing the mathematical and physical theory of the furnace, so as to place furnace design on a firm scientific basis. This book, of unusual interest to every designer, presents his conclusions, derived from experience and laboratory research, concerning the conditions and calculations to be taken into consideration for different furnace constructions.

Temperature, heat quantity, combustion, the production of high temperatures, fuel, heat transmission, and the movement of gases are discussed theoretically and in relation to furnace design, in the first half of the book. Furnace building in general is then discussed, after which chapters are devoted to regenerators and recuperators, burners and draft openings, work chambers, calculation of the laboratory working space, furnace materials, supports, starting furnaces, and heat balance. Many useful formulas are given.

KINEMATICAL DESIGN OF COUPLINGS IN INSTRUMENT MECHANISMS. By A. F. C. Pollard. Adam Hilger, Ltd., London, 1929. Cloth, 6 × 9 in., 64 pp., illus., diagrams, 4s. 9d.

The importance of the kinematical design as opposed to the usual machine-tool design of couplings in instrument mechanisms is discussed by the professor of instrument design at the Imperial College of Science and Technology, who points out that design upon kinematical principles not only minimizes variance and difficulty in adjustment, but also simplifies the problems of manufacture. The book is concerned chiefly with indicating instruments, such as ammeters, and valve-controlling instruments, such as carburetors, thermostats, governors, and spring motors.

KOMPRESSORLOSE DIESELMASCHINEN. By Friedrich Sass. Julius Springer, Berlin, 1929. Bound, 8 × 11 in., 395 pp., illus., diagrams, 52 r.m.

This textbook on the design of Diesel engines is based on the author's experience as director of the oil-engine division of the Allgemeine Elektricitäts-Gesellschaft, and his lectures at the Berlin Institute of Technology. The scientific principles involved are set forth in the opening chapters, in which fuels, ignition and combustion, the formation of mixtures, fuel injectors, fuel pumps, fuel lines, and the calculation of the main dimensions are discussed. About one-half of the book is given up to a thorough discussion of the working drawings of the principal elements of the engines, in much greater detail than is usual.

DIE KRACKVERFAHREN UNTER ANWENDUNG VON DRUCK. By Erwin Sedlaczek. Julius Springer, Berlin, 1929. Cloth, 6 × 9 in., 402 pp., illus., 45 r.m.

After a brief discussion of the theory of the cracking of petroleum, this book describes the twenty-three processes most widely used in America. On the basis of these approved methods, the author then reviews systematically the patent literature on cracking processes and apparatus. Although absolute completeness is not claimed for the book, it is a very careful compilation, which will be useful to all those interested in the cracking of petroleum.

"LUFTFAHRTFORSCHUNG." Vol. 4, Nos. 3–5; Vol. 5, Nos. 1–2. July–Oct., 1929. R. Oldenbourg, Munich and Berlin, 1929. Paper 8 × 12 in., 5 parts, diagrams, tables. Vol. 4, No. 3, 7.80 r.m.; Vols. 4 and 5, 5.40 r.m. each; Vol. 5, No. 1, 5.80 r.m.; Vol. 2, 16.50 r.m.

Luftfahrtforschung publishes the reports of the researches on aviation topics carried out at the important German laboratories and universities. These recent numbers contain investigations on engine vibrations, wing vibrations in free flight, and wind tunnels, the design of airplane frames, and the magnitudes of certain forces acting upon them.

MECHANICAL EQUIPMENT OF BUILDINGS, Vol. 1; Heating and Ventilation. By Louis Allen Harding and Arthur Cutts Willard. Second edition. John Wiley & Sons, New York, 1929. Fabrikoid, 7 × 9 in., 963 pp., illus., diagrams, tables, $10.

Brings together the theoretical and commercial data required by the designer of heating and ventilating plants for buildings of all kinds, providing a comprehensive reference book of decided practical value. The new edition has been thoroughly revised; new material has been added throughout, and many chapters have been rewritten.

MODELLVERSUCHE ÜBER DEN WASSERUMLAUF IN STEIL- UND SCHRÄGROHRKESSELN. By Karl Cleve. STRÖMUNGSERSCHEINUNGEN IN ROTIERENDEN ROHREN. By Franz Levy. BESTIMMUNG VON WÄRMEÜBERGANGSZAHLEN DURCH DIFFUSIONSVERSUCHE. By Werner Lohrisch. (Forschungsarbeiten...no. 322.) V. D. I. Verlag, Berlin, 1929. Paper, 8 × 12 in., 68 pp., illus., tables, 10 r.m.

These three reports from the Laboratory of Technical Physics at the Munich Institute of Technology deal with certain heat and circulation phenomena in boilers which have been studied but little. The first reports an investigation of the influence of diameters, lengths, pitch, contractions, and other conditions on water circulation in water-tube boilers, with measurements of the resistance to flow of water in boiler tubes. The second investigates the phenomena of flow in rotating tubes, such as are used in Atmos boilers. The third gives the results of new experiments on the transfer of heat from flowing gases to pipes perpendicular to the flow.

Errata

ON PAGE 15 of the January issue of MECHANICAL ENGINEERING, first column, third line from bottom, for "Hell Gate Station" read "East River Station."

On page 21 of the same issue, second column, 14th line, it should have been stated that the Kaplan-type turbines were installed at the Devil's River plant by the S. Morgan Smith Company. On page 22, under "Reaction Turbines," mention is made of an installation at the Waterville plant. This was made by the same company and comprises three reaction turbines of 49,000 hp. each.

On page 22, second column, 20th line, for "conical" read "cylindrical."

Page 23. Through a regrettable inadvertence the signature of Byron E. White, author of "Progress in Hydraulics," did not appear at the conclusion of his report.

Synopses of A.S.M.E. Transactions Papers

THE papers abstracted on this and following page appear in the current issues of the Materials Handling, Oil and Gas, Railroad and Wood Industries sections of A.S.M.E. Transactions. These sections have been sent to all who registered in the similarly named Divisions. Other sections are in the course of preparation and will be announced when completed, in later issues of "Mechanical Engineering."

MATERIALS HANDLING PAPERS

MATERIALS-HANDLING AND MANAGEMENT PROBLEMS OF MASS PRODUCTION. [Paper No. MH-51-7]

This is a symposium of 13 papers presented at the Management and Materials Handling Meeting of the A.S.M.E., Detroit, Mich., May 1 to 3, 1929. Titles and brief abstracts of the papers follow.

Management Applied to Materials Handling. By James Lynah. The author tells of the coordinating production, engineering, power, maintenance, and design problems which are undertaken by the Works Managers Committee of the General Motors Corporation. A staff of experts in production-engineering work, wage incentives, maintenance problems, etc., consider various phases of materials handling and devise methods for taking up slack to prevent undue accumulation, and provide rapid and efficient movement of materials through the plant.

General Survey of Materials-Handling Conditions. By John Carmody. That a great many opportunities exist for further development of methods to do work more efficiently is brought out in this paper. The author finds a great disinclination on the part of managers to use, in their own industry, methods that are producing effective results in another. Best results will come from seeking new ideas and applying them to the particular needs found. Engineers should take more ideas from one industry into another.

Materials Handling in a Forge Shop. By Hugh Dean. Handling of raw material and finished products in a modern forge shop is the problem discussed by the author of this paper. Raw stock is handled from cars to storage bins in the steel yard, and from there to the shear sheds and then to the different hammers. Work in process includes such operations as trimming, grinding, heat treating, rattling, and pickling. A new plant devoted exclusively to the manufacture of crankshafts is described. There work is made as nearly automatic as possible.

Materials Handling in the Foundry. By L. W. Pardee. Methods used to double the production of a foundry are described in this paper. As floor space was limited, the mechanical-handling equipment selected differs from what would be used if buildings and equipment were designed at the same time. Conveyors were installed for handling castings, for continuous molding, pouring, and sand handling, and for taking raw materials from the yard to the cupolas.

Cleaning and Painting of Automobile Parts. By William Pfeil. Methods of handling parts for cleaning and painting by a conveyor system are described by the author. Advantage was taken of the consolidation of work at the South Bend plant of the Studebaker Corporation to install a modern materials-handling system. The advantages of this system are illustrated by following the various processes to which fenders and sheet-metal parts are subjected. By use of the improved layout, production was increased 200 per cent.

Sheet-Metal and Body Work in Automotive Plants. By G. E. Hagemann. In the highly organized plant, sheet-metal operations are fundamentally the basis of the manufacturing cycle, and the division in which sheet-metal parts are produced requires organization and administration of the highest order. The author takes up shop layout of sheet-metal shops, handling of materials, sequence of operations, the separation of scrap, and other related topics; following which he deals with the various operations comprised in the building of automobile bodies.

Materials Handling in General Assembly. By Gordon Le Febvre. In assembly work sufficient parts must be provided at the proper time and place. The conveyor systems for accomplishing this at the Oakland plant are described by the author. A major manufacturing schedule is based on the forecast of sales. Monthly manufacturing schedules are made up for the large units, and a daily schedule provides for immediate requirements. The policy of the Oakland Motor Company is to use the most modern types of materials-handling equipment.

Material Routing to the Car-Assembly Line. By L. A. Churgay, Sr. In this paper the author tells how the particular problem of delivering parts to the car-assembly line that can not be handled efficiently by conveyors, is taken care of in the Chrysler plant. The quantities of materials to be handled are obtained from the daily production schedule. Loads were standardized, and moved at regular intervals by jitneys.

Procedure of Material Control. By Howard H. Flagg. During the past ten years an intense interest in inventory turnover has been manifest. As a result "hand-to-mouth buying" has come to form an important part of management and the systematic purchase and delivery of materials has become one of the vital functions of every manufacturing concern. Where formerly it was believed sufficient to have plenty of material at all times, it is now demanded that not only must there be always sufficient, but never too much. Such conditions cannot be attained without careful planning. To this end it has become the practice of most manufacturers to formulate in advance a tentative program for each year's output. So there has been developed the idea of monthly forecasts.

Plate-Glass Manufacture by the Continuous Process. By C. W. Avery. Trouble encountered in the development of the continuous process of plate-glass manufacture are discussed in this paper. Materials used had to be perfected, and an absolutely uniform gas pressure maintained. There were many problems in rolling, annealing, grinding, and polishing that were quite different from previous practice. Cooling of the rolls, and securing a material for them that would withstand the high temperature required considerable study. Much experimenting with the shape, weight, and speed of the various grinding wheels was necessary. After four or five years of intensive study and hard work, a good quality of plate glass was produced at about half the cost of production by old methods.

Straight-Line Production Applied to Stove Manufacture. By Alvin G. Sherman. Results obtained from use of a complete conveyor system in a stove plant are described by the author. The capacity of the assembly line is approximately 1000 stoves in 8 hr. In the porcelain plant a rotary heat-treating furnace is used. Not only are the benefits of labor saving and higher efficiency obtained through use of conveyors but a better quality of ware results.

Production Methods Used in the Electrical Industry. By E. L. Spray. The principal field for use of conveyor systems in the electrical industry is in the manufacture of devices that are operated by electric current. In this paper the author describes production methods used in the plant of the Westinghouse Electric and Manufacturing Company at Mansfield, Ohio. Sad irons, ranges, switches, waffle irons and toasters are now assembled on conveyors, and assembly costs have been reduced from 15 to 35 per cent. Results obtained include lower labor costs, reduced inventories, fewer rejects, less floor space, better processes, better machining, and a more uniform product.

Progressive Assembly in a Washing-Machine Factory. By H. M. Lane. In this paper the author tells of mold- and sand-handling equipment as installed in the aluminum and gray-iron foundry of a washing-machine plant. Conveyors were used also between the various grinding, polishing, and finishing operations with good results. For the assembling operations interrelated conveyors are used to bring the various parts together. In the spray-painting department, conveyors and continuous ovens are used.

OIL AND GAS POWER PAPERS

MAINTENANCE AND REPAIR OF MARINE DIESEL ENGINES. By Louis R. Ford. [Paper No. OGP-51-4]

The author groups motorship repairs, in general, into three classes:

(1) maintenance repairs, or those resulting from ordinary wear and tear in service; (2) repairs required as a result of faulty design, or changes due to improvement in design; and (3) repairs required as a result of accident, stress of weather, or other unusual conditions. To these might be added another classification less clearly defined, namely, unnecessary repairs—unnecessary in the sense that the need for them arises from preventable causes. He brings out the nature of the repairs most commonly required in the three general classes listed, the character of some defects developed, and some of the unusual or unexpected conditions that arise in service, by considering in turn each of the principal engine elements.

COMMERCIAL APPLICATIONS OF HIGH-SPEED OIL ENGINES. By C. H. Gibbons. [Paper No. OGP-51-5]

The author discusses the possible application of high-speed Diesel engines to aircraft, trucks, and tractors, and gives details of their application to locomotives, generating sets for city buildings, cotton ginning, oil-well drilling, pipe-line pumping, irrigation, marine propulsion, air compressors, dredges, excavating machinery, etc. He also deals with medium-speed applications and gives data for use in estimating power costs.

DIESEL POWER PLANTS FOR LARGE CITY BUILDINGS. By Edgar J. Kates. [Paper No. OGP-51-6]

In this paper the author analyzes the electric-power requirements of large buildings, and shows how they may be met by Diesel power plants. He gives figures on the economics of Diesel power in two New York buildings, one which has been in use several years, the other which is about to be built.

MODERN REFINEMENTS IN DIESEL POWER PLANTS. By Edgar J. Kates. [Paper No. OGP-51-7]

The object of this paper is to indicate that if the full value of Diesel power is to be realized, quite as much attention must be given to the design of the complete power plant as to the design of the bare engine. The author discusses the trend toward lessened attendance through the employment of automatic devices for lubrication for and maintaining reliable jacket-water and fuel supplies; the balancing of cylinder output through pyrometric measurements; reduction of costs by utilization of waste heat; elimination of noise in operation; prevention of vibration; improvement of performance, and reduction of overall power costs. It has been his experience that the cost of making a correct layout and of installing the proper refinements is fully repaid by the ensuing operating savings, and that in addition the plant performance is invaluably improved.

RAILROAD PAPERS

THE BALANCING AND DYNAMIC RAIL PRESSURE OF LOCOMOTIVES. By R. Eksergian. [Paper No. RR-51-5]

The problem of counterbalancing for minimum dynamic loading and rail stress is a basic-design limitation for modern locomotives with limited axle loads. Two methods of balance are ordinarily used; static and dynamic. As the former method is extensively used, the estimation of maximum rail pressure with the heavy overhanging revolving weights is of considerable importance. An analysis is made, resulting in formulas and general methods for the determination of the maximum rail pressure and the corresponding position of the crank for systems of revolving weights. Also, a complete outline of balancing methods is included.

AUTOMATIC TRAIN CONTROL. By G. E. Ellis. [Paper No. RR-51-6]

After briefly reviewing the early work done in automatic train control, the author recounts governmental activities regarding their installation and gives the requirements specified by the Interstate Commerce Commission. He then presents a classification of the various types of devices proposed, following this with brief descriptions of individual types. He then points out the elements necessary to the operation of all devices for automatic train control, gives figures showing the extent to which automatic train control has been adopted, and concludes with a brief discussion of the question of cost.

WOOD INDUSTRIES PAPERS

PROGRESS AND PROBLEMS RELATING TO THE USE OF SAWS IN THE PRIMARY WOOD INDUSTRIES OF THE PACIFIC NORTHWEST. Report to the A.S.M.E. Special Research Committee on Saws and Knives. [Paper No. WDI-51-7]

This report deals briefly with the change from circular to band saws; improvements in saws; reduction of power required to operate saws; choice of the best method of wood sawing; and research problems awaiting solution.

CONSERVATION OF LUMBER IN WOODWORKING PLANTS. By Carle M. Bigelow. [Paper No. WDI-51-8]

This paper gives particulars regarding a method for the installation of a differential group wage-payment plan for the cutting departments of woodworking plants. The group is paid in terms of the differential result between reduction in per cent wastage of lumber intake and board feet per man-hour production. The necessary details for accumulation of data for the installation of the method are given, the general method is completely described, and a summary of results of several typical installations given. The results are tabulated of this combined production-yield group bonus in the several major industries, as derived from actual installations extending from six months to six years.

AMERICAN MARKETS FOR TROPICAL TIMBERS. By H. M. Curran. [Paper No. WDI-51-9]

Since price levels of high-grade hardwoods now invite substitutes, the author believes a survey should be made of regions best suited to furnish our most needed supplies. He discusses the importation of Philippine timber; the need of laboratory and fabrication tests of tropical timbers suitable for American use; the exploitation, transportation, and handling of tropical timbers; and the commercial milling and marketing of such timber.

NOTE: Those who have not registered in the A.S.M.E. Materials Handling, Oil and Gas Power, Railroad and Wood Industries Divisions whose papers are abstracted on this and the previous page, and who desire copies of any of these papers, may obtain them by using the form given below.

TO THE SECRETARY, A.S.M.E., 29 West 39th Street, New York, N. Y. Date.....

Please send copies of papers checked below:

Materials Handling [MH-51-7]

Oil and Gas [OGP-51-4] [OGP-51-5] [OGP-51-6] [OGP-51-7]

Railroad [RR-51-5] [RR-51-6]

Wood Industries [WDI-51-7] [WDI-51-8] [WDI-51-9]

PRINT name (Important).....

Street Address.....City.....

Current Mechanical Engineering Literature

Selected References From The Engineering Index Service

(The Engineering Index Service is Registered in the United States, Great Britain, and Canada by the A.S.M.E.)

THE ENGINEERING INDEX SERVICE furnishes to its subscribers a Weekly Card Index of references to the periodical literature of the world covering every phase of engineering activity, including Aeronautic, Chemical, Civil, Electrical, Management, Mechanical, Mining and Metallurgical, Naval and Marine, Railway, etc. Of the many items of particular interest to mechanical engineers a few are selected for presentation each month in this section of "Mechanical Engineering." In operating The Engineering Index Service, The American Society of Mechanical Engineers makes available the information contained in some 1700 technical publications received by the Engineering Societies Library (New York), thus bringing the great resources of that library to the entire engineering profession. At the end of the year all references issued by the Service are published in book form, this annual volume being known as The Engineering Index.

Photoprint copies (white printing on a black background) of any of the articles listed in the Index may be obtained at a price of 25 cents a page. When ordering photoprints identify the article by quoting from the index item: (1) Title of article; (2) Name of periodical in which it appeared; (3) Volume, number, and date of publication; (4) Page numbers. A remittance of 25 cents a page should accompany the order. Orders should be sent to the Engineering Societies Library, 29 West 39th Street, New York.

AIRPLANE ENGINES

Air-Cooled, Heat Control in. Mathematical and Experimental Investigation of Heat Control and Power Increase in Air-Cooled Aircraft Engines, F. Gosslau. Nat. Advisory Committee for Aeronautics—Tech. Memo., no. 540, Nov. 1929, 12 pp., 25 figs. on supp. plates. Experiments conducted for Siemens and Halske Co. to determine relations between air velocity, temperature of cylinder walls, heat dissipation, cylinder dimensions, and type of construction; maximum power of present-day cylinders; increasing power by supercharging; longer strokes rather than larger bores; lower speed and larger displacement for future; racing engines. From Zeit. fuer Flugtechnik u. Motorluftschiffahrt, Oct. 7, 1928.

Manufacture. Manufacturing New Engine Models, G. W. Vaughan. Aero Digest, vol. 15, no. 3, Sept. 1929, pp. 83–86, 12 figs. Vast amount of details necessary to put new airplane engine models into production is described with outline of methods employed by Wright Aeronautical Corp.; design of tools; work of plant layout department; during progress of tool designing and plant layout, planning division is tabulating its records, and ordering and purchasing departments are sending out blueprints to vendors: work of production of materials-control departments; manufacture of airplane engines compared with that of automobile engine.

AIRPLANE PROPELLERS

Testing. Tests of Five Metal Model Propellers With Various Pitch Distributions in a Free Wind Stream and in Combination With a Model Ve-7 Fuselage, E. P. Lesley and E. G. Reid. Nat. Advisory Committee for Aeronautics—Tech. Report, no. 326, 1929, 18 pp., 20 figs. Five adjustable-blade metal model propellers tested in free wind stream and in combination with model fuselage with stub wings; propellers of same form and cross section, but with variations in radial distributions of pitch; propeller with radial distribution of pitch of same nature as that of air velocity through propeller plane suffers smallest loss in efficiency.

Theory. Contribution à la Théorie de l'Hélice Propulsive, M. Roy. (Aéro-Club de France. Travaux du Cercle d'Études Aérotechniques. Fascicule 3). Paris, Le Centre de Documentation Aéronautique Internationale de l'Aero-Club de France, 1929, 38 pp., diagrs., tables. Mathematical investigation of theories of screw propeller with special reference to airscrew; particularly, author discusses conceptions developed by Rankine and Froude concerning ideal screw, and points out certain modifications and corrections that are necessary.

AIRPLANES

Autogiros. See AUTOGIROS.

Control, Automatic. Gyroscopic Pilot Declared Success. Aviation, vol. 27, no. 20, Nov. 16, 1929, p. 990. Description of automatic gyroscopic control for airplanes recently tested out in flight of tri-engined Ford plane from Wright field; two gyroscopes, one horizontally and other vertically mounted, working on system of electrical contacts, kept craft in even position; armatures of gyroscopes are electrically driven at 15,000 r.p.m.

Design. Developing a New Model Airplane, J. Don Alexander. Aero Digest, vol. 15, no. 4, Oct. 1929, pp. 65, 278 and 280, 1 fig. Methods employed by Alexander Aircraft Co. in developing Eaglerock Bullet low-wing cabin monoplane; fast plane with low landing speed desired; reasons for selecting low-wing type; sales possibilities analyzed; strength test; control test; speed tests; spin testing; different types of retracting apparatus for landing gears tested.

Fuselages, Manufacture of. Chromium-Molybdenum-Steel Tubing Fuselage Construction, J. H. Kindelberger. Soc. Automotive Engrs.—Jl., vol. 25, no. 5, Nov. 1929, pp. 474–477, 6 figs. Reason why pilots, operators, maintenance men, designers, and manufacturers prefer welded steel to stick and wire construction for airplanes; molybdenum steel developed to make stronger struts possible; strength and reliability of welds depends on designing joints that can be welded without overheating any parts; complicated fittings should be made up into subassemblies; jigs for welding airplane assemblies, including fixtures for drilling holes in assembled frame; measures taken to prevent corrosion.

Performance Testing. Efficiency Data of Some Airplanes (Wirtschaftlichkeitszahlen einiger Flugzeuge), P. Rieppel. V.D.I. Zeit. (Berlin), vol. 73, no. 42, Oct. 19, 1929, pp. 1513–1516. Factors experimentally determined under certain conditions and in straight flying for some German and American airplanes are explained and tabulated.

Seaplanes. See SEAPLANES.

Shock Absorbers. Edgewater Shock Absorber Strut. Airway Age, vol. 20, no. 11, Nov. 1929, p. 1834, 1 fig. Description of oleo airplane strut manufactured by Edgewater Steel Co., Pittsburgh, Pa., having springs which serve dual purpose of absorbing initial shocks; through oil as well as providing necessary resiliency for taxiing; ring spring is only one-third weight of coil spring of equivalent capacity and travel; hysteresis or loss by friction amounts to 66 per cent of total energy imput.

Wings, Cantilever, Torsion in. Some Aspects of Torsion in Multispar Cantilever Wings. Air Corps Information Cir., vol. 7, no. 627, Aug. 1, 1929, 7 pp., 14 figs. Report based on study in connection with investigation of torsional stresses in propeller blades; eccentric torsion; torsion in spars of multispar wing; application to Fokker C-2; torsional properties of wing skin; single spar at same weight and strength in bending is considerably stronger and more rigid torsionally than multispar; most favorable location of single spars is at distance from leading edge equal to 25 per cent of chord; most economical cross section is square.

AIRSHIPS

Pressure Distribution. Flight Tests on U.S.S. Los Angeles, S. J. De France. Nat. Advisory Committee for Aeronautics—Report, no. 324, 1929, 33 pp., 36 figs. Full-scale pressure-distribution data on load and stresses experienced in flight by U.S.S. Los Angeles to be used in rigid airship structure design; airship turning and drag characteristics determined; stress investigation conducted by Navy Department; forces on forebody of airship relatively small; tail-surface measurements show that forces caused by gusts are much greater than those caused by horizontal maneuvers; former closely approached designed loads of tail structure. Bibliography.

ALLOYS

Aluminum. See ALUMINUM ALLOYS.

Bearing Metals. See BEARING METALS.

Brass. See BRASS.

Copper. See COPPER.

ALUMINUM ALLOYS

Corrosion. Corrosion of Aluminum Alloys in Superheated Steam (La corrosion des alliages d'aluminium dans la vapeur d'eau surchauffée), L. Guillet and Ballay. Metallurgie et Construction Méchanique (Paris), no. 44, Nov. 2, 1929, p. 17. Study of mechanical effects of corrosion; comparison of corrosion of pure aluminum and of three alloys by superheated steam. Read before Académie des Sciences.

Properties. Service Characteristics of Light Alloys, E. H. Dix, Jr. Soc. Automotive Engrs.—Jl., vol. 25, no. 5, Nov. 1929, pp. 463–468 and (discussion) 468. Discussion of aluminum and magnesium, in their pure and alloyed states, as most suitable for aircraft construction; physical properties; effects of adding small quantities of alloying elements; heat treating for increasing strength per unit weight of alloys; effect of natural aging and artificial aging at elevated temperatures and of quenching in hot and cold water after heat-treating; several types of corrosion; protection afforded to aluminum alloys by surface coating of pure aluminum.

Protective Coatings. Some Recent Developments in Protective Coatings for Aluminum and Its Alloys, H. Sutton. Metal Industry (Lond.), vol. 35, no. 18, Nov. 1, 1929, pp. 411–412 and (discussion) 412–414. Brief survey of recent developments in production of protective coatings on metals; anodic oxidation of aluminum and its alloys; chlorides undesirable; scope of anodic process; Jirotka process; Stafford O'Brien process; anodic treatment of steel; application of

pure aluminum; coatings of metallic aluminum; electrodeposits on aluminum.

APPRENTICES

Training. Apprentice Training Pays Dividends, F. L. Prentiss. Iron Age, vol. 124, no. 20, Nov. 14, 1929, pp. 1293–1298, 6 figs. Description of methods employed by Warner & Swasey Co., Cleveland, which resulted in new high standards in developing young men for responsible executive and technical positions; plant executives are school graduates; probationary period important test; aim is to train production experts; complete records kept of boys' work.

AUTOGIROS

Theory. Theory of the Autogiro, J. de la Cierva. Aero Digest, vol. 15, no. 4, Oct. 1929, pp. 124 and 126, 1 fig. Principles involved in design of autogiro are discussed; because of its aerodynamical nature autogiro is not subject to any risks of stalling; contrary to what most aerodynamicists think, mass of air influenced every second is much larger than that corresponding to volume equal to product of surface of rotor by speed of descent.

AUTOMOBILE ENGINES

Diesel. See DIESEL ENGINES, Automotive.

Fuel Distribution. Report on Air-Fuel-Ratio Tests, H. W. Best. Soc. Automotive Engrs.—Jl., vol. 25, no. 5, Nov. 1929, pp. 532–533 and (discussion) 534, and 536–541, 2 figs. Tests conducted to determine how air-fuel ratios obtained by analyzing exhaust gases checked with ratios obtained by measuring air and fuel are described, test having been made on 6-cylinder 3½- by 5-in. engine and air measured by using Durley air box having 2-in. flat-plate orifice; three methods of obtaining air-fuel ratios from exhaust-gas analyses were used and compared.

Indicator Cards. Interpretation of the Indicator Card, R. N. Janeway. Soc. Automotive Engrs.—Jl., vol. 25, no. 5, Nov. 1929, pp. 478–487 and (discussion) 487–488, 4 figs. True thermodynamic interpretation of indicator card must be based upon properties of actual medium working in engine, taking into account actual nature of heat liberation; by use of diagram heat balance can be drawn up which accounts for distribution of entire heat input and output; process is quantitatively evaluated and heat liberation during normal combustion period and during expansion separated so that extent of loss due to after burning is revealed; determining tendencies toward explosion roughness.

Manufacture. New Cylinder Line Reduces Packard Costs, C. O. Herb. Machy. (N. Y.), vol. 36, no. 3, Nov. 1929, pp. 169–173, 8 figs. Extensive changes made in manufacturing methods of Packard Motor Car Co. are described, in which latest types of machine tools, work-handling conveyors, and unusual chip disposal installation make higher efficiency possible; all four sides of cylinder blocks are milled in drum-type continuous machines; eight cylinders are bored simultaneously; using five drills up to 30 in. long successively; machining valve seats and valve-stem guide holes; 116 holes drilled at one time; assembling valve-stem guides in minimum time.

White Iron Edges on Machined Surfaces of Cylinder Heads and Blocks Are Responsible for Economic Losses, G. M. Eaton. Automotive Industries, vol. 61, no. 22, Nov. 30, 1929, pp. 792–794, 3 figs. Results of investigation recently made in causes of white iron edges in several specific epidemics of this trouble; unalloyed iron, chrome-nickel irons, and chrome-molybdenum irons investigated; fundamental reductions of the trouble can be made by modifying foundry design and pattern practice in way that will remove fin on rough casting.

AUTOMOBILE PLANTS

Continental Motors. Continental Motors' New Plant Has Central Assembly Line Fed From Each Side by Self-Contained Departments, J. Geschelin. Automotive Industries, vol. 61, no. 22, Nov. 30, 1929, pp. 788–791 and 794, 8 figs. Description of new redesigned plant of Continental Motors which is employed for making 21 distinct engine models to specifications of 78 different customers; realignment of machinery partitions, storage bins and fixtures, just completed, permits of daily changes in production schedules; noteworthy feature of assembly line is line inspector, who works up and down line, noting carefully various steps in process.

Heat-Treating Furnaces. Automatic Heat-Treating Unit, W. M. Hepburn. Iron Age, vol. 124, no. 20, Nov. 14, 1929, pp. 1304–1306, 4 figs. Description of three interconnected furnaces installed at Studebaker Plant for purpose of normalizing, hardening, quenching, and drawing; these functions may be separated for various heat treatments, according to requirements of production; furnaces are fired with both gas and oil, gas burners being used in soaking-zone; waste-heat recuperator.

AUTOMOBILES

Bearings, Friction of. Automotive Research—Friction-Coefficient Research, L. Illmer. Soc. Automotive Engrs.—Jl., vol. 25, no. 5, Nov. 1929, pp. 545–546. Test contributions of J. Goodman to friction research outlined; author's work along analytical research lines toward practical solution of bearing-design problem discussed; journal friction controlled by pressure factor; advantages of tabulated constants of coefficients.

Brakes. The Marelli Vacuum Servo Brake. Rubber Age (Lond.), vol. 10, no. 9, Nov. 1929, p. 357. Brake is designed to operate four-wheel brakes and can be fitted into any existing brake gear; effect is to reduce braking pressure smoothly and without effort; rubber employed in vacuum servo is outcome of practical experience, being of special high quality to resist temperature variations, cured by special process and carefully tested before being passed for assembling.

Production Control. Manufacturing Control Through Economic Size of Production Lots, F. E. Raymond. Soc. Automotive Engrs.—Jl., vol. 25, no. 5, Nov. 1929, pp. 453–462, 2 figs. Formulas for size of lot that can be manufactured most economically are given; it is shown when change should be made to continuous production; such factors as cost of space for finished stores and return on investment in finished parts considered; lots indicated are not absolute quantities but are designated in form of economic ranges that are practicable until there is marked change in sales or other conditions; formulas also applied to help determine type of handling equipment that will be most economical to use.

Springs and Suspensions. Suspension. Automobile Engr. (Lond.), vol. 19, no. 260, Nov. 7, 1929 (Special Number), pp. 427–429, 11 figs. Trends in design of automobile suspension as shown in cars exhibited at Olympia are discussed; overshadowing of all other types of suspension by four semi-elliptics is most noticeable feature; comparison of ten types of springs exhibited on American, British, and Continental cars; only type of springing which is competitive, although far behind is semi-elliptic front and cantilever rear combination; very few springs fitted with sliding ends; independent springing is represented by Steyr only.

Testing. Performance Evaluation. Automobile Engr. (Lond.), vol. 19, no. 259, Oct. 1929, 387–388, 2 figs. Description of Tapley performance meter for testing general efficiency of motor vehicles; object is to furnish direct reading evaluations of performance, giving measure in pounds per ton that engine is exerting on driving wheels; methods of measuring top gear acceleration, hill-climbing capacity, tractive resistance, actual power output, and engine friction.

AUTOMOTIVE FUELS

Developments in. Developments in Motor Fuels, D. P. Barnard. Soc. Automotive Engrs.—Jl., vol. 25, no. 5, Nov. 1929, pp. 495–498, 2 figs. Progress in improving fuels for carbureter-type internal-combustion engine must be directed toward securing greater efficiency and reliability in operation, and flexibility; for automobiles cost of fuel on basis of useful work realized per dollar expended is more important than weight; for aircraft, increased cost of power cost must be balanced against increased pay-load possibilities; effect of improving distribution and anti-knock characteristics; Federal Specifications restrict improvement; limitation of sulphur content justified.

Synthetic. Problem of Synthetic Liquid Fuels (Le problème des carbutants synthétiques), R. Etienne. Echo des Mines et de la Métallurgie (Paris), vol. 57, nos. 3003 and 3004, Aug. 20 and Sept. 1, 1929, pp. 651–653 and (correction) 689. Review of research undertaken to solve problem of supplying automotive fuels, of paramount importance in wartime to nations that lack supplies of natural petroleum; importance of hydrogenation of lignite, production from which in 1929 is estimated at 250,000 tons. Abstract of paper read before School of Mines, Paris.

B

BALANCING MACHINES

Dynamic type. Mechanization in Dynamic Balancing, G. Gerber. Eng. Progress (Berlin), vol. 10, no. 11, Nov. 1929, pp. 287–289, 5 figs. Principles and types of machine are described; dynamic balancing machine of 2200 lb. capacity is described.

BEARING METALS

Bronzes. Wear Tests on Bearing Bronzes, W. M. Corse. Iron Age, vol. 124, no. 22, Nov. 28, 1929, pp. 1431–1434, 2 figs. Results of tests carried on for Chicago Bearing Metal Co., to determine important physical properties of group of copper-tin-lead alloys within limits of chemical composition and constitution ordinarily applied industrially in railroad journal boxes; chill-cast bronze bearings wear faster in tests but are more resistant to repeated pounding and static tension; for mechanical strength lead content should be kept near lower limit of 12- to 25-per cent range.

BEARINGS

Friction in. Friction in Journal, Roller, and Ball Bearings in Intermittent Operation (Reibung in Gleit-, Rollen- u. Kugellagern bei aussetzendem Betrieb), L. Klein. V.D.I. Zeit. (Berlin), vol. 73, no. 2, Oct. 19, 1929, pp. 1499–1502, 10 figs. Experiments in laboratory for conveying equipment in engineering University of Hanover have shown that for friction and anti-friction bearings, friction in intermittent operation is higher than in permanent run and is dependent on relative time of throwing in and out; in both cases friction reaches minimum value only after hours of operation; friction coefficients for various cases.

[See also AUTOMOBILES, Bearings.]

Journal. Journal-Bearing Practice, F. Hodgkinson. Engineer (Lond.), vol. 148, no. 3854, Nov. 22, 1929, pp. 559–562, 8 figs.; and (discussion) pp. 543–544, 3 figs.; see also Engineering (Lond.), vol. 128, no. 3332, Nov. 22, 1929, pp. 690–693, 6 figs., and (discussion) pp. 681–864, 8 figs., and editorial comment, pp. 679–680. Author considers principally problems of bearings for such machines as dynamos, motors, steam turbines, and like, where flooded lubrication is applied and machinery must be placed in operation with full unit load on bearing.

BELT DRIVE

Losses in. Losses in Belt Drives Employing Small Pulleys (Verluste in Riementrieben bei Verwendung kleiner Scheiven), A. E. Mueller. Maschinenbau (Berlin), vol. 8, no. 20, Oct. 17, 1929, pp. 685–689, 12 figs. Classification of belt losses; equipment and experiments for determination of no-load losses; analysis of losses; periodicity and extent of bending resistance; effects on life of belts; influence on inside greasing, etc.

BOILER FEEDWATER

Analysis. Rational Measurement Coefficient for Water Analysis (Rationale Masszahl fuer die Wasseranalyse), A. Sulfrian. Waerme (Berlin), vol. 52, no. 47, Nov. 23, 1929, pp. 867–869, 1 fig. Instead of coefficient of hardness which, it is claimed, is on arbitrary basis, "milli" standard unit is proposed, which, author states has scientific basis; relations between milli-unit, degrees of German hardness, milligram substance per liter and standard solution are shown in alignment chart.

BOILERS

Baffles Fire-Tube. Modern Progress in Fire-Tube Baffles (Neuere Fortschritte an Flammrohr-Einbauten), D. Schulz. Glasers Annalen (Berlin), vol. 105, no. 4, Aug. 15, 1929, pp. 67–68, 3 figs. Increase of flue-gas temperature and increased fuel economy have been attained by use of firebrick which frequently destroyed through sudden fluctuations in temperature; this is prevented by newly patented system, called "Stabilsteine," which is described.

Control. Electric Boiler Control (Die elektrische Kesselregelung), W. Jaekel. Elektrizitaet im Bergbau (Munich), vol. 4, no. 11, Nov. 18, 1929, pp. 208–212, 13 figs. Equipment of Siemens and Schuckert, making exclusive use of electric processes; main object is to obtain favorable combustion at highest efficiency; features of system are discussed.

Rouchka System of Automatic Boiler Control (Les Regulateurs automatiques et les Appareils de Controle Roucka dans les Chaufferies Modernes). Technique Moderne (Paris), vol. 21, no. 15, Aug. 1, 1929, pp. 17–18, 1 fig. System developed by E. Roucka at his electrical-instrument works in Czechoslovakia during war, provides completely automatic control over flue dampers, air admission, feedwater supply and rate of grate travel, thus reducing work of stokers to general supervision and checking regularity of firebed; every important central station in Czechoslovakia is fitted with Roucka apparatus: there are more than 150 installations in Germany.

Corrosion. Decomposition of Effloresecnce on Leaking Boilers Due to Flue Gases (Zersetzung von Ausbluehungen an undichten Kesseln durch die Rauchgase). Zeit. des Bayerischen Revisions-Vereins (Munich), vol. 33, no. 20, Oct. 31, 1929, pp. 279–280. Results of investigation of effloresecnce on boiler supplied with feedwater

softened according to lime-soda process; it is shown that flue gases have disintegrating effect on such incrustations.

Feed Circuits. Modern Feed Water Circuits, J. Sims. Elec. Times (Lond.), vol. 76, no. 1985, Nov. 7, 1929, pp. 773–775, 22 figs. Layouts for feedwater circuits, de-aerators, feed heaters, etc., are discussed and illustrated by diagrams; binary-fluid cycle is estimated to give overall thermal efficiency of 32.5 per cent.

Seamless. Seamless Boilers for Very High Pressure (Somlose kedeltomler for meget joje tryk), A. Hannover. Tekniske Forenings Tidsskrift (Copenhagen), vol. 58, no. 5, Apr. 1929, pp. 69–79, 14 figs. Manufacture of seamless boiler 13.5 m. long, 1.5 m. diam. with wall thickness of 114 mm. is described; boiler was tested at 112 atmos.; materials used in boilers for high pressures are pointed out.

Waste-Heat. A Composite Exhaust Gas Boiler. Engineer (Lond.), vol. 148, no. 3851, Nov. 1, 1929, p. 476, 1 fig. Details of special water-tube vertical boiler, built by Cochran and Co., which can be simultaneously employed for oil firing and recovery of waste heat from exhaust gases of marine oil engines; first boiler of this new type was installed on motor vessel "Sheaf Holme;" boiler is furnished with two upper nests of tubes for waste-heat recovery and lower nest of tubes for oil firing, which latter tubes are in direct communication with furnace.

Cochran-Doxford Combination Boiler. Mar. Engr. and Motorship Bldr. (Lond.), vol. 52, no. 626, Nov. 1929, pp. 440–441, 5 figs. Excellent results obtained with new type of boiler designed to utilize waste heat from two-stroke-cycle engine with moderate supplementary oil firing.

Water Circulation in. Experiments Concerning Water Circulation in Boilers (Versuche ueber den Wasserunlauf in Dampfkesseln) E. Schmidt. V.D.I. Zeit. (Berlin), vol. 73, no. 33, Aug. 17, 1929, pp. 1151–1155, 9 figs. It is shown by experiment that self-evaporation is cause of frequently observed reversed water circulation; theory of water circulation has to take self-evaporation and relative velocity in boilers into consideration.

Water-Tube, Danks-Netherton. The "Danks-Netherton" Water-Tube Boiler. Colliery Guardian (Lond.), vol. 139, no. 3593, Nov. 8, 1929, pp. 1775–1777, 3 figs. Description of vertically inclined sectional design of water-tube boiler, sections being relatively small units; arrangement of setting of section may take any form suitable for different systems of combustion used in modern boiler practice.

BRASS

Hard, Properties of. Properties of Hard Brass (Die Eigenschaften des Hartmessings MS 58), O. Bauer and K. Memmler. Mitteilungen der deutschen Materialpruefungsanstalten, no. 8. Berlin, Julius Springer, 1929, 76 figs., tables and diagrams, 13.50 R.M. Properties of different standard brass varieties were investigated at request of German Industrial Standards Committee by Staal, Materialpruefungsamt and Kaiser-Wilhelm Institut fuer Metallforschung in Berlin-Dahlem; material was supplied by different firms made by different processes, and are to some extent of different chemical composition (varying lead content); methods and results of tests are described.

C

CABLEWAYS

Drive. Influence of Karlik Pulley on Stress of Cable and on Type of Cableway Drive (Der Einfluss der Karlikscheibe auf die Beanspruchung des Zugseiles, etc.), A. Schurig. Foerdertechnik u. Frachtverkehr (Wittenberg), vol. 22, nos. 20 and 21, Sept. 27 and Oct. 11, 1929, pp. 383–384 and 407–408, 10 figs. Advantages and disadvantages of multiple-groove pulleys with and without differential gear; Karlik pulley and its influence on decrease of bending stresses, bearing pressure, stresses in rope, durability, safety, and simplification of driving machinery.

CARS

Hopper Scale Test Car. Hopper Scale Test Car, Kansas Grain Inspection Department, T. B. Armstrong. Scale Jl., vol. 16, no. 1, Oct. 1929, p. 7, 3 figs. Description of steel, 42 ft. hopper scale test car; equipment of car includes furnished office for scale inspector, 10,000 lb. of 50-lb. sealed test weights, weight baskets, jacks, anvil, forge, press drill, emery, and buffer; also equipped with 8-hp. Cushman engine and hoist with steel cable for hoisting weights to top of elevators; description of test procedure.

Refrigerator. North American Develops Mechanical Refrigerator Car. Ry. Age, vol. 87, no. 20, Nov. 16, 1929, pp. 1155–1157, 4 figs. Advantages claimed for new mechanically refrigerated car include saving of approximately 3000 lb. in weight over standard refrigerator with full ice bunkers, elimination of all icing and reicing en route, maintenance of any predetermined constant temperature required for best conditioning of perishable food products, attainment of this result without sacrifice of load-carrying capacity, and complete absence of salt and brine drippings; power obtained from truck axle; operation of refrigeration system.

Truck Stresses on Curves. The Calculation of the Stresses Set Up in a Bogie Frame Running Through a Curve, F. Legein. Int. Ry. Congress Assn.—Bul. (Brussels), vol. 11, no. 9, Sept. 1929, pp. 1547–1559, 3 figs. Stresses tending to deform in horizontal direction are due mainly to horizontal thrusts exerted by axles when rounding curves; article indicates method of thrust calculation for frame design; it is found that stresses tending to deform frame in horizoatal plane are equal and opposite, and directed along diagonal of rectangle formed by axes of axles and of axle guards.

CAST IRON

High-Test, Manufacture of. High-Test Cast Iron, R. S. MacPherran. Am. Foundrymen's Assn.—Trans., vol. 37, 1929, pp. 495–500 and (discussion) 729–733, 5 figs. Methods employed by Allis-Chalmers Mfg. Co. in producing high-test cast iron, are discussed; secret of high-test iron seems to be low carbon and high temperature on melting; silicon from 1.50 to 3.00 per cent has been varied without materially affecting strength of test bar; variation due to low melting point of ferro-silicon, small size of ladle, and some large castings made with silicon below 1.80 per cent.

Machinability. Fins Cause Unmachinable Castings, G. M. Eaton. Iron Age, vol. 124, no. 22, Nov. 28, 1929, pp. 1446–1448, 3 figs. Results of investigation made into causes of white-iron edges, in several specific epidemics of this trouble, including unalloyed irons, chrome-nickel irons and chrome-molybdenum irons; chill to white iron on castings from mixtures already adjusted for highest practicable strength and hardness; designers and foundries both responsible; either molybdenum or nickel alloyed into iron tend to combat white-iron edges; fundamental reduction of white-iron edges can be made by modifying designs and patterns in way that will remove fins from critical locations.

Properties. Modern Engineering Cast Irons and their Properties, J. C. Pearce. Engineer (Lond.), vol. 148, no. 3852, Nov. 8, 1929, p. 504. Abstract of paper read at British Cast Iron Association, dealing with relationship between size and strength in cast iron; it is pointed out that bar of gray iron, 0.875 in. in diam., cast in given mixture, is stronger than bars of larger diameter cast from same metal at same time, and that specific strength diminished as section increased; cast iron behaves much better than might be expected when subjected to fatigue tests; resistance of cast iron to wear still remains one of unsolved problems.

Recent Views on the Mechanical Properties of Cast Iron, Thum. Foundry Trade Jl. (Lond.), vol. 41, no. 688, Oct. 24, 1929, p. 302. In order to explain its low strength, cast iron is compared with steel having same percentage of combined carbon; it is proved experimentally that steel behaves elastically in way similar to cast iron when its structure is broken by holes and slits; suggestions are given for utilizing figures obtained for deflection at fracture by transverse test for vibrational strength which is very valuable when investigating suitability of cast iron for manufacture. Paper presented before German Foundry Employers' Federation.

CASTINGS

Cleaning. Tests on a Hydraulic Fettling Plant, U. Lohse. Foundry Trade Jl. (Lond.) vol. 41, no. 685, Oct. 3, 1929, p. 240. Process for cleaning castings with jet of water at high pressure forced through small-diameter nozzles which are placed directly on castings to be fettled; results of tests carried out on machine in foundries of Lanz, Mannheim; castings weighed before and after being fettled in order to ascertain how much sand was removed from casting in given time; wet fettling method is thus suitable for any molding material. Abstract of paper presented before German Iron Founders Employers Federation.

X-Ray Analysis. X-Ray Inspection of Castings. Soc. Automotive Engrs.—Jl., vol. 25, no. 5, Nov. 1929, p. 551. Value of X-ray analysis of castings is discussed; its solution to problem of over-zealous and careless inspectors; X-ray inspection used successfully in examination of cast steel, bronze and aluminum as well as other articles.

COMPRESSED-AIR MOTORS

Hele-Shaw-Beacham. Hele-Shaw-Beacham Air Motor. Mar. Engr. and Motorship Bldr. (Lond.), vol. 52, no. 626, Nov. 1929, p. 455, 2 figs. Firm of Holman Bros., Camborne, have introduced simple form of air motor developed from Hele-Shaw pump; new motor is robust, simple piece of mechanism that owes its development to combined efforts of S. H. Hele-Shaw and J. Beacham; its design should render it particularly suitable for operation of ships' winches, windlasses, and steering gear.

COPPER ALLOYS

Hardened. Hardened Copper for Electrical and Chemical Equipment, W. N. Hibbard. Iron Age, vol. 124, no. 22, Nov. 28, 1929, p. 1434. Uses and properties of hardened coppers known as Everdur and Tempaloy and their welding characteristics are described; table shows composition and physical properties of soft and hardened copper; hardened copper alloys are strong or stronger than medium carbon steels; cold-rolled alloys weld easily and will not season or corrosion crack. Abstract of paper presented before Int. Acetylene Assn.

COUPLINGS

Flexible. The Carrier-Ring Flexible Coupling. Engineering (Lond.), vol. 128, no. 3329, Nov. 1, 1929, pp. 557–558, 7 figs. Coupling consists of five main parts, comprising two coupling disks, or bodies, two halves of protective cover, and carrier ring; shaft couplings, which consist of flanged disks keyed on to respective shafts, have notches on their perispheres corresponding with springs and giving them appearance of pinions.

CRANES

Floating. New Type of Floating Crane for Port of Hamburg (Neuartige Schwimmkrane im Hamburger Hafen), O. Wundram. V.D.I. Zeit. (Berlin), vol. 73, no. 43, Oct. 26, 1929, pp. 1547–1548, 3 figs. Description of Diesel-engine floating crane of 25 tons capacity; dimensions of crane barge are 26 m. by 14.7 m. by 2.67 m., welding construction of barge results in saving of 30 tons in weight; two-cylinder, 4-stroke, compressorless Diesel engine is 120 hp. capacity and of 90 to 375 r.p.m.

Gears and Gearing. Worm Gears versus Tooth Gears in Modern Crane Design (Schneckengetriebe oder Zahnraduebersetzung in modernen Kranbau), E. Goldberger. Foerdertechnik und Frachtverkehr (Wittenberg), vol. 22, no. 17, Aug. 16, 1929, pp. 309–314, 5 figs. Efficiency of double-geared transmissions; motor capacity; relation of various losses in operation; relative efficiency; current consumption; heat absorption; circumferential force on brake drum; numerical example.

CRANKSHAFTS

Multi-Throw. Stiffness of Multi-Throw Crankshafts, H. Constant. Engineering (Lond.), vol. 128, no. 3329, Nov. 1, 1929, pp. 548–549, 10 figs. Review of paper published by British Aeronautical Research Committee; author measured deflections of component of series of crankshafts; there is large difference between calculation and observation in neighborhood of holes in web; these holes are found to become oval under strain, and this diminishes apparent stiffness of throw; stiffness is also affected if ends of arm are chamfered or beveled.

CUTTING TOOLS

Tungsten Carbide. An Appraisal of Carbide Tools, Z. Jeffries. Iron Age, vol. 124, no. 21, Nov. 21, 1929, pp. 1367–1371, 3 figs. Discovery of tungsten carbide, method of manufacturing carbide tools, representative performance in various uses, and future influence of tungsten-carbide cutting tools are discussed; cutting materials which no other metallic material has been able to cut; extraordinary production on metal work; tools for intermittent or jump cuts. Abstract of paper presented before Am. Soc. Mech. Engrs.

D

DIES

Forging, Heat Treatment of. American vs. British Die-Tool Treatments, J. W. Urguhart. Mech. World (Lond.), vol. 86, nos. 2233 and 2234, Oct. 18 and 25, 1929, pp. 373–374 and 386–387. Oct 18: Review of compositions and method of hardening forging dies in England and America; tempering limits of drop-hammer die block; composition; forging-machine die-block requirements; some hot-pressing die steels; chromium-

steel die tools difficult to machine; English die steels. Oct. 25: Carburized plain and nickel-steel die blocks; essential carburization condition; hammer work and normalizing; shock-resisting nickel steels; heat-application points of importance.

DIESEL ENGINES

Automotive. F. B. Stearns Develops Two-Cycle Overhead-Camshaft Diesel Engine of the Solid-Injection Type, A. F. Denham. Automotive Industries, vol. 61, no. 21, Nov. 23, 1929, pp. 748–750, 3 figs. Description of two-cycle 6-cylinder engine with overhead camshaft and pressure-scavenging solid injection, which has been developed by F. B. Stearns; power plant, under test since last April, is out of experimental stage; in its present form it can be used for rail-cars and motor boats, and may prove of value in air transport.

Widespread Development of Automotive Diesels Is Not Anticipated, H. M. Crane and A. L. Clayden. Nat. Petroleum News, vol. 21, no. 48, Nov. 27, 1929, pp. 81, 84, and 91. Abstract and commentary by Clayden, of address by Crane before National Petroleum Assn.; discussion of popular idea that Diesel is fundamentally better than gasoline motor and eventually supplants it; opinion is expressed that, except for certain limited fields, it is highly improbable that automotive Diesels will ever be nearly as suitable as gasoline engines.

Design. Recent Developments in the Airless Injection of Fuel in Diesel Engines. Sulzer Tech. Rev. (Switzerland), no. 3, 1929, 23 pp., 39 figs. Three main tendencies in development of Diesel engines in recent years have been: (1) increasing size of engine; (2) developing small high-speed type; and (3) means employed to introduce fuel and improved combustion; problems arising when considering introduction of necessary quantity of fuel at right moment; importance of duration of injection; illustrated description of accumulating valves for Diesel engines.

Fuel Injectors. Design of Injection System Determines Fuel Consumption, A. Peters. Power, vol. 70, no. 21, Nov. 19, 1929, pp. 789–790, 4 figs. Author claims that tests he has run prove that variable stroke fuel pump is superior to by-pass controlled pump for high-speed solid-injection Diesels.

High-Pressure. High-Pressure Diesel Engines (Zur Frage der Hochdruckdieselmaschine), C. Commentz. Maschinen-Konstrukteur (Leipzig), vol. 62, no. 20, Oct. 15, 1929, pp. 461–462. Economic factors entering in design of high-pressure Diesel engines, i.e., use of material, and cost of construction in relation to fuel consumption, are discussed; author quotes figures from American practice.

Marine (Richardsons-Westgarth). Development and Performance of the Richardsons-Westgarth Oil Engine, W. S. Burn. Shipbldg. and Shipg. Rec. (Lond.), vol. 34, no. 20, Nov. 14, 1929, pp. 589–591, 1 fig. Author shows development of design, described by him in 1926, as result of intervening three years' work; double-acting two-stroke engine has proved very satisfactory; from time to time trouble was occasioned, mostly from mysterious causes; tendency has been slightly to increase weight and width; crankshaft is now made with cast-steel webs with integral balance weights; fuel-injection experiments. Abstract of paper before North-East Coast Instn. of Engrs. and Shipbldrs.

Marine—Supercharging. The Werkspoor Supercharging System. Mar. Engr. and Motorship Bldr. (Lond.), vol. 52, no. 626, Nov. 1929, pp. 448–450, 3 figs. New system of supercharging has been developed in connection with Werkspoor four-stroke crosshead-type engines; system consists in closing in lower sides of working pistons and providing space with automatic air suction and delivery valves; piston displacement serves to compress air to moderate pressure.

DIPHENYL

Properties of. Vapor Pressure and Heat of Vaporization of Diphenyl, J. Chipman, and S. B. Peltier. Indus. and Eng. Chem., vol. 21, no. 11, Nov. 1929, pp. 1106–1108, 1 fig. Vapor pressure of diphenyl has been determined between 162 and 322 deg. cent.; equation is derived which should be valid for extrapolation up to 10 to 15 atmospheres; vapor density has been determined and heat of vaporization calculated; properties of diphenyl are shown to be in accord with those of other aromatic hydrocarbons.

DRILLS

Power Requirements of. Power Required to Drill Cast Iron and Steel, O. W. Boston and C. J. Oxford. Am. Soc. Mech. Engrs.—Advance Paper, no. 4, for mtg. Dec. 2–6, 1929, 22 pp., 55 figs. Test data given for torque, thrust, and net horsepower developed at point of drill for some high-speed-steel twist-drills when cutting various steels and cast iron; thrust for both cast iron and steel increased in direct proportion to drill diameter; commercial drilling tests; in attempt to correlate hardness values determined by Brinell, Rockwell, scleroscope, and Herbert pendulum hardness testers, with drilling test results, no satisfactory relation was found; machinability constants must be determined from actual drilling tests.

E

ECONOMIZERS

Gilled Tubes for. Gilled Tubes, G. Tansley and O. Kubalek. Engineer (Lond.), vol. 148, no. 3853, Nov. 15, 1929, p. 532, 2 figs. Account of experiments with gilled tubes for economizers; number of B.t.u.'s transmitted per degree difference was highest with plain tube and lowest with deep gill; outer periphery of deep gill was very much less effective than inner periphery; results from properly designed gill cast on tube will be approximately equal to results from plain tube per square foot of heating surface. Abstract of paper read before Instn. Engrs. and Shipbldrs. in Scotland.

ELECTRIC FURNACES

Foundry. Short-Cycle Malleableizing Improves Product and Saves Time. Elec. World, vol. 94, no. 20, Nov. 16, 1929, p. 989, 2 figs. New short-cycle annealing process for production of malleable iron castings by which it is possible to produce malleable iron in 30 hr. or less, has been announced by General Electric Co.; furnace and control panel for short-cycle annealing are illustrated.

ELECTRIC WELDING

Atomic-Hydrogen. The Welding of Ferrous and Non-Ferrous Metals by the Atomic-Hydrogen Flame, H. A. Weinman. Aviation Eng. vol. 2, no. 11, Nov. 1929, pp. 13–15, 14 figs. Atomic-hydrogen welding process, and equipment used is described; upon entering atomic-hydrogen welding flame, portion of gas is made to pass through an electric arc, remainder merely serving to replenish envelope of molecular hydrogen around arc; welding tungsten, molybdenum, cast-iron alloy steels, aluminum and its alloys, brass and nickel; process is used to weld metals and alloys presenting difficulties to other forms of welding.

F

FLOW METERS

Quantity-Rate. Quantity-Rate Fluid Meters, E. S. Smith, Jr. Am. Soc. Mech. Engrs.—Advance Paper, no. 40, for mtg. Dec. 2 to 6, 1929, 21 pp., 11 figs. Study of correlation of coefficients and expansion factors, using Reynolds' number and acoustic velocity ratio; venturi tubes and square-edged orifices are placed upon common basis and graphical methods of use are shown; example illustrating relation between flow similarity, Reynolds' number, and coefficient; study of factors which cause departure from theoretical flow conditions; fluid metering in practice; basic formula for quantity-rate meters; venturi-tube and orifice analysis. Bibliography.

FLOW OF FLUIDS

Similarity Applied to. Similarity: Limitations in Its Application to Fluid Flow, J. M. Spitzglass. Am. Soc. Mech. Engrs.—Advance Paper, no. 42, for mtg. Dec. 2–6, 1929, 9 pp., 8 figs. General historical review of development of theory of fluid-flow, since Torricelli, in 1643, to most recent studies of 1929, with special reference to geometrical and hydraulic similitude; author concludes that hydraulic similarity being matter of experiment; large sizes may or may not show same results as smaller ones. Bibliography.

FLOW OF GASES

Thermodynamics. Impact Losses in Flow of Gases and Vapors Through Sudden Expansions in Pipe Lines (Stossverlust an ploetzlichen Erweiterungen in Rohren beim Durchfluss von Gasen und Daempfen), A. Busemann and W. Nusselt. V.D.I. Zeit. (Berlin), vol. 73, no. 44, Nov. 2, 1929, pp. 1588–1589, 4 figs. Theoretical debate of phenomenon on basis of general thermodynamic principles; entropy diagrams.

FOUNDRIES

Continuous Production in. Economies of Continuous Production, Especially in Foundries (Wirtschaftliche Fertigung durch Fliessarbeit unter besonderer Berueecksichtigung der Giesserein), C. Rein. Giesserei (Duesseldorf), vol. 16, nos. 32 and 33, Aug. 9 and 16, 1929, pp. 714–724 and 746–762, 18 figs. Notes on molding-sand preparation and handling; conveying of castings to cleaning room; arrangement of cranes; cleaning shop with floating conveyance system; cupola charging; inclined elevators; conveyors in core and molding shops; comparison of different molding methods.

FUELS

Automotive. See AUTOMOTIVE FUELS.

Calorific Value. Gross or Net Calorific Values. World Power, vol. 12, no. 70, Oct. 1929, pp. 370 and 373. It is important to avoid confusion and error which are likely to arise from indiscriminate use of gross and net calorific values of fuel used without clearly specifying which basis is taken; American practice leans toward gross calorific values of fuel, while continental practice is more frequent to use net or lower calorific value; discussion of proximate and ultimate analysis of fuel.

Economy. Some Fuel Problems D. Brownlie. Engineering (Lond.), vol. 128, no. 3331, Nov. 15, 1929, pp. 649–650. Editorial review of paper read before Institution Mechanical Engineers; increase in size of power stations in last decade greatly improves prospect of making commercial success of low-temperature carbonization; in plant installed at Dunstan in 1925, 14 cwt. of smokeless fuel are produced per ton of coal fed; in addition, 35,000 cu. ft. of gas per ton of raw coal fed are discharged from top of retort; 26 per cent of all coal burned in American power stations is pulverized.

G

GAS ENGINES

Blast-Furnace-Gas. Modern Blast Furnace Gas Engines, F. J. Taylor. Gas and Oil Power (Lond.), vol. 25, no. 289, Oct. 3, 1929, pp. 3–5, 4 figs. Practicability of slow-burning properties of blast-furnace gas in large slow-running gas engine; discussion of pistons and valves, governor design; waste-heat recovery and blowing engines.

GAS TURBINES

Lorenzen. The Lorenzen Exhaust-Gas Turbine (La turbina a gas di scarico Lorenzen), R. Schulz. Notiziario Tecnico di Aeronautica (Rome), vol. 8, no. 10, Oct. 1929, pp. 109–115, 5 figs. Principles of design and operation of compressive type of turbine and its accessory parts. Italian translation of article published in Luftwacht.

GASES

Heat Conductivity. Instruments to Measure Heat Conductivity (Varmeledningsinstrumenter), C. A. Robak. Teknisk Ukeblad (Oslo), vol. 76, no. 24, June 14, 1929, pp. 249–251, 6 figs. Method of measuring heat conductivity of several gases are described, also instruments used and results of three tests on reliability of instruments to measure contents of hydrogen in air.

GEARS

Cutting. Determination of Back Lash With a Given Tooth Profile (Ermittlung der Gegenflanke bei gegebenem Zahnprofil), F. Roetscher. V.D.I. Zeit. (Berlin), vol. 73, no. 41, Oct. 12, 1929, pp. 1469–1471, 9 figs. Simple method is described for determining back lash for given tooth profile which also permits determination of tooth form produced in any cutting machine according to helicoidal system; action of different parts of cutting machine is followed and better conception of phenomena occurring with gear generation of gears is thereby obtained.

Planetary. Planetary Gearing Calculations and Design, W. Richards. Machy. (Lond.), vol. 35, no. 889, Oct. 24, 1929, pp. 105–109, 5 figs. Large reductions possible with planetary gear trains are taken up; general arrangement of planetary reduction gear; method of tabulating results of movements; planetary reduction gear with driving and driven members rotating in same direction; law governing direction in which driven gear revolves; center distances and pitches of planetary gears.

Surface Hardening. Surface Hardening. Automobile Engr. (Lond.), vol. 19, no. 259, Oct. 1929, pp. 377–378, 5 figs. Description of mechanically operated process for treatment of gears; surface hardening of steel by means of oxy-acetylene flame; Shorter installation in Huddersfield works for spur gears up to 16 ft. in diam. helical

gears up to 3 ft. in diam. and bevel gears up to 3 ft. 6 in. in diam., ranging from 7 to 1 diametral pitch; mechanical head, and tank and wheel holding pedestal; process intended to produce fully hardened martinsitic band of sufficient width and depth to increase life of wheels without distorsion.

GOVERNORS

Centrifugal. Critical Valuation of Various Centrifugal Spring Governor Systems (Betrachtungen ueber die kirtische wertung verschiedener Fliehkraft-Feder-Regler-Systeme), F. Heinzmann. Maschinen Konstrukeur (Leipzig), vol. 62, no. 20, Oct. 15, 1929, pp. 466–468, 7 figs. Study based on numerical examples for different types of standard equipment, intended to determine how far their efficiency meets requirements of practice.

GRINDING MACHINES

Alignment. Alignment Tolerances on Precision Grinding Machines. Machy. (Lond.), vol. 35, no. 890, Oct. 31, 1929, pp. 141–142, 7 figs. Description of range of special alignment tests developed by Churchill Machine Tool Co., Manchester, for all classes of precision grinding machines; method of checking perpendicularity of wheel-head slideway vee; checking alignment of tables as it travels along ways; checking of alignment of wheel head spindles with bed slideways in both vertical and horizontal directions; tolerances met on Churchill Cincinnati grinding machines.

Hydraulic Drive. High-Speed Grinding Machines With Hydraulic Feed. Engineering (Lond.), vol. 128, no. 3330, Nov. 8, 1929, pp. 589–590, 2 figs. Details of machines made by Karl Jung, Berlin, designed for precision work on small parts; in internal grinding machine, small diameter of grinding wheel necessitates very high shaft speeds to obtain desired peripheral speed; machine under consideration has been designed so that spindle speeds of as high as 30,000 r.p.m. may be safely obtained; surface grinding machine differs in application of hydraulic principle from internal grinding machine in that, in this case, works is traversed by oil gear and grinding wheel by hand.

GUNS

Grinding. Grinder for Reconditioning Bores of Naval Guns, R. H. Raube. Machy. (N. Y.), vol. 36, no. 3, Nov. 1929, p. 223, 1 fig. Description of gun grinder for reconditioning bores of large naval guns, recently developed by Hutto Engineering Works, Inc., Detroit, Mich. for reconditioning 12-, 14-, and 16-in. guns; support for spindle used in grinding full length of rifling of these guns is provided by seven centralizing rests; grinding head driven by 7½-hp. d-c. motor.

H

HARDNESS TESTING

Brinell. The Hardness of Steel Balls Used for the Determination of Brinell Hardness Numbers of Materials, R. G. Batson and S. A. Wood. Dept. Sci. and Indus. Research—Special Report, no. 16, 1929, 30 pp., 3 figs. Description of research to enable specifications to be prepared for hardness of steel balls used for Brinell hardness testing; hardness tests using diamond indenting tool and by ball flattening method; crushing strength of balls by three-ball method; determination of hardness numbers of steel specimens of high and uniform hardness when made with balls of different hardness; file tests on balls.

HEAT EXCHANGERS

Heat Transmission in. Heat Transfer in Cross-Current Heat Exchangers (Der Waermeuebergang im Kreuzstromwaermeaustauscher), G. Zimmermann. Zeit. Bayerischen Revisions-Vereins (Munich), vol. 33, nos. 19 and 20, Oct. 15 and 31, 1929, pp. 267–270 and 280–283. Oct. 13: Theoretical discussion; calculation of temperature field resulting from heat transfer in cross current according to Nusselt. Oct. 31: Tests were carried out in experimetal plant; main purpose was to determine relation of heat transfer and transmission coefficients to velocity; two fans were installed, one for air and one for flue gas.

HEAT-INSULATING MATERIALS

Testing. Tests of the Properties of Insulating Materials, O. R. Randall. Engineering (Lond.), vol. 128, no. 3331, Nov. 15, 1929, pp. 657–659, 6 figs. Discussion of certain methods which may be used to investigate properties of insulating materials; attempt is made to place testing of such material upon more exact footing than has previously been in use. Paper read before Brit. Assn. at Johannesburg.

HEAT TREATMENT

Air Effects. Effect of Atmospheres on the Heat Treatment of Metals, E. G. de Coriolis and R. J. Cowan. Indus. and Eng. Chem., vol. 21, no. 12, Dec. 1929, pp. 1164–1168, 1 fig. Effects of various atmospheres on metals during typical heating operations ranging from 350 to 2500 deg. fahr.; these effects are shown to be essentially of chemical nature; methods for application of heat are considered; account is given of research work of American Gas Assn. in connection with forging; problem of bright annealing is considered; use of steam for bright annealing of copper is discussed.

HONES

Micromatic. Jeschke Micromatic Hone Expands Automatically. Automotive Industries, vol. 61, no. 20, Nov. 16, 1929, p. 717, 3 figs. Description of production hone with automatic expanding head, manufactured by Micromatic Hone Corp.; throw-out attachment raises tools out of cylinder bore, eliminating manual backing off; predetermined gage prevents oversized finishing.

HYDRAULIC TURBINES

Bearings. The Development of the Water-Turbine, R. W. Miller. Mech. World (Lond.), vol. 86, no. 2236, Nov. 8, 1929, pp. 442–444, 7 figs. Design of Escher-Wyss and other thrust bearings and method of lubricating bearings explained; method of taking away heat generated so that friction coefficient is maintained within safe limits; upper thrust rings divided into inner and outer rings.

Design. Raanaasfoss Power Station—Reconstruction of a Turbine, H. Thoresen. Engineer (Lond.), vol. 148, no. 3852, Nov. 8, 1929, pp. 492–493, 3 figs. Notes on redesigning No. 4 turbines by makers, J. N. Voith, Germany; first move was to re-erect old model in research laboratory and carry out fresh tests; from test data obtained full-sized runner was erected in casing of No. 4 turbine, and relationship between efficiency curves was retested; it was decided to remove dividing wall of turbine; considerable increase in efficiency is very largely due to careful model tests.

Rebuilding a Turbine at Raanaasfoss Power Station (Ombygning av en turhin ved Raanaasfoss kraftanlegg), H. Thoresen. Teknisk Ukeblad (Oslo), vol. 76, no. 42, Oct. 16, 1929, pp. 429–431, 3 figs. As turbine did not show expected efficiency, new tests were made with models and new runner for turbine was made and installed in old casing; results of investigations and tests made; efficiency of new wheel is 89.8 per cent.

Governors. Present Tendency in Methods of Hydraulic-Turbine Control (Les tendances actuelles en matière de regulation des turbines hydrauliques), M. Barbillon. Technique Moderne (Paris), vol. 21, no. 15, Aug. 1, 1929, p. 487. Action of several types of governors is mentioned, including mixed indications of tachometer and accelerometer; double indication of Neyret-Beylier-Picard and Pictet governor, which has been installed on 4000-kw. unit at Beauffort, Savoy, since 1925; and Ateliers des Charmilles governor.

Pressure Control. Mechanics of Hydraulic-Turbine Pressure Regulation, A. Pfau. Am. Soc. Mech. Engrs.—Advance paper no. 34, for mtg. Dec. 2–6, 1929, 17 pp., 20 figs. Paper describes mechanical means whereby desired field results can be obtained under existing conditions of operation and of pipe-line charactistics; calculations, formulas, and examples of speed and pressure control take up such points as closing gates, passing through position of static balance of turbine gates, formulas for speed regulation, effect of pressure variations on speed, and calculations of pressure rises in pipe lines.

Propeller. Increased Kilowatt Output of Adjustable-Blade Propeller Turbines, C. R. Martin. Am. Soc. Mech. Engrs.—Advance paper, no. 28, for mtg. Dec. 2–6, 1929, 6 pp., 8 figs. Review of development and placing in service of adjustable-blade runners in United States; comparative discussion of efficiency characteristics of fixed-blade and adjustable-blade propeller turbines; adjustable runner makes it possible to obtain average plant efficiency as high as that of Francis runner; advantage of adjustable-blade propeller runner lies in increased kilowatt-hour output combined with lower overall cost.

Kaplan Turbines at the Ryburg-Schworstadt Plant on the Upper Rhine, D. Thona. Am. Soc. Civil Engrs.—Proc., vol. 55, no. 10, Dec. 1929, pp. 2561–2563 and (discussion) 2563–2565. General features of propeller turbines designed for maximum discharge of 11,000 cu. ft. per sec.; runner diameter 23 ft.; outputs 42,000 hp. at 75 rev. per sec.; steps in development of Kaplan turbine; advantages and efficiencies; Kaplan turbines in Sweden.

Speed Control. Changing Requirements in Hydraulic Turbine Speed Regulation, F. Nagler. Am. Soc. Mech. Engrs.—Advance Paper, no. 32, for mtg. Dec. 2–6, 1929, 6 pp., 8 figs. Hydraulic engineer of Allis-Chalmers Manufacturing Co., discusses design and operation of governing equipment of hydraulic turbines with special reference to flyball control and oil-pressure speed-reducing mechanism; discussion is illustrated with examples from practice of Louisville Hydro-Electric Co., Conowingo power plant, etc.

I

IMPACT TESTING

Notched-Bar. Fractures in Steel and Significance of Transition Region of Notch Toughness (Die Brucharten des Stahles und die Bedeutung des Uebergangsgebietes der Kerbzaehigkeit), F. Fettweis. Stahl und Eisen (Dusseldorf), vol. 49, no. 45, Nov. 7, 1929, pp. 1621–1627, and (discussion) 1627–1628, 11 figs. Transition region follows in all cases same laws; explanation of occurrence of fractures must take into consideration crystalline nature of metal grains; attempts to explain these fractures are not satisfactory because they are also applicable to amorphous bodies and too general; also, they are contrary to facts and not always logical.

INDUSTRIAL MANAGEMENT

Production Control. See AUTOMOBILES.

Quality Control. Step-by-Step Inspection in the Factory, W. Hutchinson. Management, vol. 33, no. 4, Nov. 1929, pp. 43–46 and 74–75. System of progressive factory inspection that checks quality of product from receipt of raw material to shipping of finished article is described.

INTERNAL-COMBUSTION ENGINES

Design. Pressures in Combustion-Chamber Engines (Der Druckverlauf im Zuendkammermotor), H. Ruehle. Zeit. fuer Technische Physik (Leipzig), no. 10, 1929, pp. 465–472, 7 figs. Graphical mathematical method of solution of differential equations is applied to problem of machine design and it is shown how difficult calculations can be made clear by systematic treatment.

Thermodynamics. The Thermodynamics of Heat Transference, A. A. Herzfeld. Automobile Engr. (Lond.), vol. 19, no. 259, Oct. 1929, pp. 374–376, 3 figs. Calculations affecting output of internal-combustion engines are given; only turbulent flow considered is developing formulas for heat transference during combustion and expansion in high-speed engine; formulas of von Karman and Latzko; flow conditions in cylinder analyzed; border gas layer for various piston positions; calculation of duration and rate of propagation of combustion; mass rate of combustion; influence of dissociation on combustion.

Vibration. Study of Vibrations in Expansion Line of High-Speed Internal-Combustion Engines (Untersuchungen der Schwingungserscheinungen in der Expansions-linie bei raschlaufenden Verbennungs-Krafmaschinen, K. Voelckel and H. Kissinger. Automobiltechnische Zeit. (Berlin), vol. 32, nos. 30 and 31, Oct. 31, and Nov. 10, 1929, pp. 670–672 and 702–703, 12 figs. Theoretical and practical investigations of nature of vibrations in high-speed engine; tests were carried out on single-cylinder Horex engine making use of optical indicator of OSA-Apparate Gesellschaft, Frankfort; relation of fuel to vibration was determined, which lead to conclusions regarding cause of vibrations.

[See also AIRPLANE ENGINES; AUTOMOBILE ENGINES; DIESEL ENGINES; GAS ENGINES; MOTOR BUSES; OIL ENGINES.]

L

LIGHTING

Industrial. The Elements of Good Factory Lighting, D. W. Thorpe. World Power, vol. 12, no. 70, Oct. 1929, pp. 337–342, 9 figs. Illustrated description of good and efficient factory lighting; consideration of lighting-points to be adopted in general lighting; article considers aspect of good factory lighting with relation to efficiency.

LOCOMOTIVES

Compound. Eight-Coupled Compound Tank Engine, Paris, Lyons and Mediterranean

Ry. Locomotive (Lond.), vol. 38, no. 447, Nov. 15, 1929, p. 354. Brief description of four-cylinder compound locomotive; cylinders 15.5 in. and 24.8 in. by 25.7 in.; drive is divided, high-pressure cylinders connected to second coupled axle; while low-pressure cylinders drive first; coupled wheels 1650 mm.; weight of engines in working order 115 tons; total length over buffers 58 ft. 6 in.

Diesel. Requirements of Locomotive Design for Diesel-Engine Drive (Die Anforderungen des Lokomotivbaues an den Dieselmotor), F. Meineke. V.D.I. Zeit. (Berlin), vol. 73, no. 42, Oct. 19, 1929, pp. 1509–1512, 9 figs. Until now Diesel engines have been too expensive and complicated in construction to be efficient; this especially concerns drive between motor and driving wheels as Diesel engines of common design have been used; railroad practice requires suitable engine of constant performance in large range of speeds; requirements concerning design and performance of such engines are discussed.

Superheater. A Note on Superheating and Locomotive Cylinder Efficiency, E. L. Diamond. Engineer (Lond.), vol. 148, no. 3854, Nov. 22, 1929, pp. 541–543, 4 figs. There appears to be no information of detailed character as to exact behavior of steam in locomotive cylinder under varying running conditions; writer reconstructed quantitatively two series of indicator diagrams taken at Pennsylvania Railroad Co.'s locomotive testing plant at Altoona; these relate to E6S 4–4–2 and K4S 4–6–2 superheater locomotives; he suggests that it would be worth while to discover just how locomotive efficiency varies with superheat.

Switching. Eight-wheel Switchers for the Missouri Pacific. Ry. Age, vol. 87, no. 20, Nov. 16, 1929, pp. 1139–1141, 6 figs. Description of 25 switching locomotives to handle 85-car trains in transfer service; ten burn oil and 15 are fired with soft coal; cylinders 25 in. by 28 in.; total engine and tender weight of coal locomotives is 393,300 lb. and for oil burning 380,800 lb.; total engine and tender wheel base 53 ft. 4 in.; driving wheels 51 in.; steam pressure 198 lb.; rated tractive force 57,750 lb.

Wheels, Pressure of. Dynamic Pressure of Locomotive Wheels (Ueber den dynamischen Druck der Lokomotivraeder), G. Lomonossoff. Glasers Annalen (Berlin), vol. 53, nos. 5 and 6, Sept. 1 and 15, 1929, pp. 80–84 and 92–98, 12 figs. Mathematical analysis regarding dynamic effect of vibrations and forces of locomotive mechanism and of stresses upon springs, rails, and bridges.

LUBRICANTS

Greases, Zinc Oxide. An Electroplating Lubricant. Indus. Chem. (Lond.), vol. 5, no. 57, Oct. 1929, p. 412, 1 fig. As result of corrosion in Keenok friction gears when using ordinary lubricants and due to electrolytic action set up by differences in electric potential, firm of Keenok Gears Limited has introduced new lubricant; zinc oxide was chosen as most suitable material for lubricant; results from practical point of view has been to eliminate wear of parts.

Oil Viscosity. More Recent Results Concerning Viscosity of Lubricants Under Pressure (Neuere Ergebnisse ueber die Druckzaehigkeit von Oelen), S. Kiesskalt. V.D.I. Zeit. (Berlin), vol. 73, no. 42, Oct. 19, 1929, pp. 1592–1503, 1 fig. Former experiments of author are completed on basis of later American experience; exponential equation for increase of viscosity under pressure is confirmed and more simple relation between sensitivity for temperatures and for pressure are indicated with aid of curves. See reference to earlier work in Engineering Index, 1928, p. 504.

M

MACHINERY

Foundations, Vibrations of. Vibration of Foundations (Ueber Fundamentschwingungen), H. Kayser, V.D.I. Zeit. (Berlin), vol. 73, no. 37, Sept. 14, 1929, pp. 1305–1310. Principles of new methods for computing resonance by means of energy equations; report on observations and measurements of vibrations of turbine foundations; comparison of calculated and observed results; effect of nature of foundation site; deadload compensation for dynamic stresses.

MALLEABLE-IRON CASTINGS

Bridge Rails. Making Large Malleable Castings, E. F. Cone. Iron Age, vol. 124, no. 21, Nov. 21, 1929, pp. 1364–1366, 5 figs. Employment of large malleable-iron castings as railings for new Liberty Bridge which spans Monongahela River in downtown district of Pittsburgh is discussed; posts and railings stand severe tests.

Manufacture. Malleable Iron Castings Produced in the Cupola (Kupolofen Temperguss). O. Brauer. Zeit. fuer die Gesamte Giessereipraxis) (Berlin), vol. 50, nos. 44, 45, and 46, Nov. 3, 10, and 17, 1929, pp. 373–375, 383–384, and 391–392, 6 figs. Author seeks to show how good and cheap malleable castings can be produced at short notice and in large quantities, without costly plant reconstruction and additions or entirely new plant.

MATERIALS

Granular, Heat Conductivity of. Method for Determinaton of Thermal Conductivity of Pulverulent Substances at High Temperatures (Ueber ein Verfahren zur Bestimmung der Waermeleitfaehigkeit pulverfoermiger Koerper hohen Temperaturen), M. Pirani and Wangenheim. Zeit. fuer Technische Physik (Leipzig), no. 10, 1929, pp. 413–424, 7 figs. Method, experimental arrangements and equipment for determination at high temperatures and for different materials; measured values of various materials are given in tables and curves, and discussed.

MATERIALS HANDLING

Industrial Plants. Modernizing the Factory Handling System, G. E. Hagemann. Am. Mach., vol. 71, no. 21, Nov. 21, 1929, pp. 852–855, 8 figs. Discussion of the why, the what, and the how of mechanical materials handling in smaller manufacturing plants; check list is given of points to be covered in any materials-handling survey made to modernize plant; factors of product, processing, handling, and economy. Paper presented before Associated Industries of Massachusetts.

METALS

Fatigue of. Endurance and Fatigue of Metals (Dauer und Ermuedungsfestigkeit) E. Trebesius. Maschinen Konstrukteur (Leipzig), vol. 62, no. 20, Oct. 15, 1929, pp. 459–460. General outline of fatigue and endurance properties in metal machine parts; author emphasizes that designer should take proper cognizance of phenomena under discussion, and by adequate proportioning change natural vibration of parts in order to avoid critical super-position of frequencies.

The Fatigue of Metals. Engineer (Lond.), vol. 148, no. 3855, Nov. 29, 1929, p. 584. According to Gough, in whole experience of National Physical Laboratory, no case has been encountered in which slip bands indicative of plastic yielding have not been apparent at stresses which would never fatigue material; surface defects have considerable influence on lowering fatigue strength; this, taken in conjunction with demonstration that fatigue strength is reduced by contact with liquids which produce chemical effect on metal, leaves little room for doubt that fatigue failure commences at surface of metal.

Solidification. Volume Changes During the Solidification of Metals and Alloys, W. E. Goodrich. Engineering (Lond.), vol. 128, no. 3331, Nov. 15, 1929, p. 659. Results of measurements made on behalf of Die Casting Committee of British Non-Ferrous Metals Research Association, on metals of low fusibility, viz., tin, lead, bismuth, antimony, and their alloys. Brief abstract of paper read before Faraday Soc.

Spraying. Treatment With Chemicals Improves Metal-Sprayed Surfaces. Iron Age, vol. 125, no. 21, Nov. 21, 1929, p. 1371. Problems pertaining to metal spraying are discussed; rapid formation of protective skin of zinc oxide on sprayed coating is of great importance; durable aluminum coatings produced by treating layer with acids and carbonates; spraying with aluminum as protection against high temperature; spraying with tin more satisfactory when subsequent chemical treatments have been applied. From Swiss Welding Jl.

X-Ray Analysis. X-Ray Methods for Determining of Flaws in Construction Materials (Roentgenverfahren zur raeumlichen Ausmessung von Fehlstellen in Werkstoffen), C. Kantner and A. Herr. V.D.I. Zeit. (Berlin), vol. 73, no. 24, June 15, 1929, pp. 811–816, 24 figs. Principles of densographic and stereometrometric processes giving results of great precision far exceeding that of usual methods; description of special apparatus and method of using it, with special reference to study of flaws in castings and welds.

MOTOR BUSES

Engines, Heavy-Oil. Surveys the Present State of Progress of Heavy Fuel Engines and Their Possibilities, G. J. Shave. Bus and Coach (Lond.), vol. 1, no. 10, Oct. 1929, pp. 380–386, 5 figs. Possibilities which compression-ignition motor offers of utilizing wide field of cheap fuel; expenditure necessary for comprehensive research is sound investment; advantages and disadvantages of heavy-oil fuel; fuels available; combustion problems; heavy-oil vaporizers; vaporizer limitations; compression-ignition engines; fuel injection; constant-stroke pumps; heavy-fuel engines; fuel injectors; Diesel engine types; starting; maintenance and repair.

MOTOR TRUCKS

Design. Motor Vehicle Design, J. B. Osler. Modern Transport (Lond.), vol. 22, no. 557, Nov. 16, 1929 (Supp. Sec.), pp. xxi and xxiii, 1 fig. Discussion of proper vehicle design and effect on motor-fleet operation; diagram showing operating cost per mile at various vehicle speeds; maintenance expenditure.

Present Practice and Trends in Truck Design, B. B. Bachman. Am. Mach., vol. 71, no. 20, Nov. 14, 1929, pp. 825–826. Increasing use of pneumatic tires and demands for higher speeds are requiring more powerful engines and many other changes; smaller wheels, better brakes both front and rear, and engines with more cylinders, are mentioned as changes probable in truck design. Abstract of paper presented before World Engineering Congress, Tokio.

Karrier. A 6–8-Wheeler. Motor Transport (Lond.), vol. 49, no. 1284, Oct. 21, 1929, pp. 485–487, 7 figs. Description of articulated 6- or 8-wheeled motor truck produced by Karrier Motors Ltd., which has been put into service by London, Midland and Scottish Railway; time-saving arrangements for coupling and uncoupling tractors and trailer portions; truck can be used at any time as tractor and 4-wheeled trailer; trailer portion is of experimental design; Alcyl lubrication system; four-cylinder engine rated at 22.5 hp.; tractor has pneumatically worked hoist by which forward end of trailer can be quickly raised off ground.

N

NOISE

Measurement of. Measurement of Machine Noises, B. A. G. Churcher and A. J. King. Elec. Times, vol. 76, no. 1986, Nov. 14, 1929, p. 816, and (discussion). Comprehensive investigation carried out by Metropolitan-Vickers Electrical Co.; work was initiated with object of attacking in thorough and comprehensive manner problem of noise emitted by motors, but technique and measuring apparatus developed in connection with sound tests on motors are also directly applicable to other classes of apparatus. Paper read before Instn. Elec. Engrs.

O

OIL ENGINES

Combustion in. Ratio of Mixture and Combustion Processes in Oil Engines (Mischungsverhaeltnis u. Verbrennungsvorgaenge im Oelmotor), P. Meyer. V.D.I. Zeit. (Berlin), vol. 73, no. 24, June 15, 1929, pp. 824–826, 3 figs. Reference to earlier suggestions for determination of mixture ratio from exhaust-gas analysis; exact determination of constituents of combustion gases in self-mixing and injection engines in case of lack of air; combustion tests in bomb showed deviations in self-mixing engines; attempt to explain this phenomenon is made.

P

PINS

Machinery. The Mills Grooved Pin. Machy. (Lond.), vol. 35, no. 887, Oct. 10, 1929, pp. 51–52, 9 figs. Description of grooved pins, developed by James Mills, Ltd., Stockport, for securing machine parts that eliminate expensive screwing and tapping; principle of pin is that of taper wedge in form of spring; parallel pins of suitable quality of steel; has three grooves pressed into it symmetrically in such was as to form three raised sectors.

POWER PLANTS

Steam Accumulators for. Ruth's Accumulator for Peak Loads and for Standby Service in Electric Power Plants (Ruthsspeicher zur Spitzendeckung und als Momentanreserve in Elektrizitaetswerken), E. Praetorius. Elektrizitaetswirtschaft (Berlin), vol. 28, no. 490, Aug. 2, 1929, pp. 432–435, 4 figs. Momentary standby service as applied in plant in Malmo, Sweden, connected

with municipal heating systems; systems of Munich, Elberfeld, Leipzig, Charlottenburg, etc.; savings and cost of energy; equipment load and wiring diagram of Charlottenburg plant are illustrated.

PRESSES

Drawing. Modern Pneumatic Drawing Equipment (Neuzeitliche Druckluft-Ziehanlagen), O. Kuehner. Werkstattstechnik (Berlin), vol. 23, no. 19, Oct. 1, 1929, pp. 556–560, 18 figs. Details of new designs for which it is claimed that increased economy is obtained by protection of tools and possibility of using less accurate materials; machines described are made by L. Schuler, Goeppingen, Germany.

PRESSURE VESSELS

Wall Thickness. Non-Ferrous Metal Walls for Pressure Vessels (Die Wandungen der Dampffaesser aus Nichteisenmetallen), G. Hoennicke. Waerme (Berlin), vol. 52, no. 45, Nov. 9, 1929, pp. 835–841, 7 figs. Two examples are given of results obtained with cylinder plates of non-ferrous metal, described in Feb. 16 and 23, 1929, issues of this journal; riveted joint of cylinder exposed to internal pressure and its influence on thickness of plate; calculation of all parts of pressure-vessel walls with uniform degree of safety is recommended.

PUMPS, CENTRIFUGAL

Performance. Characteristics of Centrifugal Pumps, E. L. Maag. Power House, vol. 23, no. 21, Nov. 5, 1929, pp. 17–21, 5 figs. Diagrams illustrating characteristic curves of 6- and 16-in. single-stage pump; importance of curves for designing engineer; diagram illustrating characteristic curves of 8- and 10-in. two-stage pumps.

PYROMETERS

Radiation. "Pyropto" a Radiation Pyrometer (Strahlungspyrometer Pyropto). Zeit. fuer die Gesamte Giessereiprazis (Berlin), vol. 50, no. 40, Oct. 6, 1929, pp. 343–345, 5 figs. Description of instrument placed on market by Hartmann and Braun, Frankfurt; it consists of telescope inside of which, between lenses, incandescent lamp is built.

R

RAIL MOTOR CARS

Fuels. Distillate as Rail-Car Fuel, E. Wanamaker. Soc. Automotive Engrs.—Jl., vol. 25, no. 5, Nov. 1929, pp. 499–501, and 514. Reasons for interest of Rock Island Railroad in use of internal-combustion engines; fuel requirements of internal-combustion engines; manufacture of petroleum products outlined and place of distillate among them indicated; distillate has physical properties similar to those of kerosene, but chemical differences that prevent it from burning on wick; relative prices of gasoline and distillate at refinery; comparative prices for future; specification for distillate.

Gasoline-Electric. Gas-Electric Motor Car Transportation on Steam Railroads, P. M. Gilliland. South. and Southwest Ry. Club—Proc., vol. 28, no. 5, Sept. 1929, pp. 15–52 and (discussion) 53–61, 16 figs. General application of rail motor cars to reduce operating costs in cases where local traffic is on decline; brief history of motor car development; scheme of operation; maintenance and care of operation; operating results; oil-electric locomotives.

RAILROAD SIGNALS

Automatic Block. Automatic Block Signals Protect Train Movements. Ry. Signaling, vol. 22, no. 11, Nov. 1929, pp. 410–411, 3 figs. Either-direction signals on double-tract line controlled automatically by approach of train through Canadian Pacific Connaught Tunnel; track and signaling layout; train establishes direction for signal control; auxiliary equipment.

REFRIGERATION

Research. Methods of Obtaining Extremely Low Temperatures (Sur la manière dont on obtient les températures très basses), W. H. Keesom. Revue Universelle des Mines (Liége), vol. 72, no. 8, Oct. 15, 1929, pp. 225–233, 13 figs. Description of method developed in cryogenic laboratory at Leiden; historical reference to liquefaction of ammonia gas in 1798, and helium in 1908, both accomplished in Holland; description of refrigeration research work of Kamerlingh Onnes; description of apparatus and practice in obtaining temperature of 2.3 deg. Kelvin, at which liquid helium exhibits properties differing from liquid helium at higher temperature.

REMOTE CONTROL

Optical Indicator. Remote Control With Pictorial Indication (Sinnbildliche Fernanzeige), Ahrens. Foerdertechnik und Frachtverkehr (Wittenberg), vol. 22, no. 23, Nov. 8, 1929, pp. 439–440, 5 figs. Special type of electric position indicator developed by Siemens and Halske, to be used for movable bridges, sluices, ship control, etc., and which give plastic pictorial idea of position of moving parts remotely operated.

ROLLING MILLS

Billet Mills, Design of. Improvement of Billet Mills (Die Entwicklung des Platinenwalzwerkes), W. Kraemer. Stahl und Eisen (Dusseldorf), vol. 49, no. 46, Nov. 14, 1929, pp. 1653–1654, 1 fig. Recommendations are made to improve efficiency of billet mills and reduce costs; plan of suggested mill for production of billets is shown as continuous mill is too costly, improved universal mill with Lauth three-high mill is proposed.

Hydraulic Drive. Hydraulic Drive of Rolling Mills and Conveyors (Hydraulische Antriebe fuer Walzwerke und Foerderanlagen), E. Riecke, K. Maleyka and A. Huwiler. Stahl und Eisen (Dusseldorf), vol. 49, no. 46, Nov. 14, 1929, pp. 1657–1664, 16 figs. Polemic concerning hydraulic gear developed by Huwiler; Riecke compares this electrohydraulic drive to electric drive, and concludes that Ilgner drive is such satisfactory solution of problem that it will maintain its supremacy permanently; Maleyka is also of opinion that successful application of hydraulic drive must await important as yet unsolved problems; reply of Huwiler is appended.

Journal Bearings. New Types of Journal Bearings in Rolling Mills (Neue Gleitlagerformen in Walzwerken), H. Weinlig. Stahl u. Eisen (Dusseldorf), vol. 49, no. 44, Oct. 31, 1929, pp. 1573–1579, 19 figs. Further development of bearings at Roechling iron and steel works in Woelklingen; bearings with linked chambers; pressure lubrication; testing of different kinds of wood to determine their adaptability; comparative experimental results; wood-frame bearing has been used successfully in different mills.

Time Study in. Study of Efficiency of Rolling Mills by Means of Time Studies (Untersuchung der Leistung einer Walzenstrasse durch Zeitstudien), O. Kasper. Archiv fuer das Eisenhuettenwesen (Dusseldorf), vol. 3, no. 5, Nov. 1929, pp. 383–389, 15 figs. Simple examples are given to demonstrate principles of time studies; it is not helpful to carry out thousands of separate measurements, but systematic investigation of work should be conducted to obtain data on processes which cannot be properly estimated by other means.

S

SEAPLANES

Design. Large Flying Boats (Die Gross-Flugboote), Schuster. Glasers Annalen (Berlin), vol. 105, no. 7, Oct. 1, 1929, pp. 105–111, 8 figs. Problems to be solved in designs of seaworthy seaplanes, i.e., resistance and power requirements of flying boat at starting, and increase in weight when type of boat is enlarged; most important German and foreign flying boats are summarized; typical design of Rohrbach and Dornier flying boats.

Dornier. The Dornier "Do. X" Seaplane. Engineering (Lond.), vol. 128, no. 3332, Nov. 22, 1929, p. 686, 2 figs. Brief general particulars wing span 48 m., 157 ft. 6 in., length 40.05 m., 131 ft. 5 in., and height 33 ft., maximum beam of hull is 19 ft. 8 in.; power plant consists of 12 Siemens-Jupiter air-cooled engines rated at 500 hp. each and mounted in six nacelles above wing.

SOLIDS

Viscosity in. Viscosity in Solids, R. L. Wegel. Bell Laboratories Rec., vol. 8, no. 3, Nov. 1929, pp. 94–99, 5 figs. Distortion of piece of solid matter is generally accompanied by two kinds of energy losses: thermodynamic losses due to changes of volume, and losses due to shearing between layers of material; these shearing viscous losses are discussed.

SPEED REDUCERS

Variable Speed. An Infinitely Variable Speed Gear. Gas and Oil Power (Lond.), vol. 25, no. 289, Oct. 3, 1929, p. 18, 1 fig. Description of infinitely variable-speed gear manufactured by Crofts, Ltd.; speed ranges from zero to 1000 r.p.m. and above, also reverse; great advantage is of bringing machinery to rest or at any desired speed.

SPRINGS

Coil. Oscillations of Compound Springs, A. S. Langsdorf. Wash. Univ.—Sci. and Technology, no. 3, Oct. 1929, 17 pp., 4 figs. In order that springs of compound type may be designed to minimize oscillations under given operating conditions, it is necessary to analyze their performance by mathematical methods, so as to derive formulas in terms of spring constants; accordingly, analysis has been worked out to cover any general case.

STEAM CONDENSERS

Surface. Large All-Welded Condenser Successfully Operating at Parr Shoals. Power, vol. 70, No. 21, Nov. 19, 1929, pp. 786–789, 6 figs. Surface condenser recently placed in operation at the Parr Shoals station, Parr, S. C., is unique not only because it is first large all-welded surface condenser built for land use, but also because of method of construction and suspension that eliminates tube packing, gives complete freedom for thermal expansion and leaves space beneath body of condenser entirely free of structural support.

Modern Surface Condensing Plant and Feed Systems, J. Evans. World Power (Lond.), vol. 12, no. 71, Nov. 1929, pp. 487–492, 5 figs. Theoretical discussion of condenser design; list of requirements of efficient condenser and auxiliaries of power unit; calculation of cooling surface; single and double-pass condensers. Paper read at Liverpool Eng. Soc.

STEAM-ELECTRIC POWER PLANTS

Deepwater, N. J. Deepwater—A New Idea in Central Stations. Power Plant Eng., vol. 33, no. 22, Nov. 15, 1929, pp. 1204–1214, 11 figs. Deepwater is one of first large central stations to go into operation utilizing 1200 lb. pressure exclusively and is also one of first to supply large quantities of high-pressure exhaust steam to industrial plant; coal delivered both by rail and water; boilers to be operated at 1350 lb. drum pressure; forced and induced draft; heat balance diagram of Deepwater; feedwater system; make-up feedwater is evaporated; list of principal equipment is given; turbine generators; condensing equipment; electrical features; instruments and metering.

England. The Hams Hall Generating Station of The Birmingham Corporation. Engineering (Lond.), vol. 128, nos. 3329, and 3332, Nov. 1 and 22, 1929, pp. 545–547 and 663–666, 18 figs. partly on supp. plate. Nov. 1: First section, now finished, comprises 60,000 kw., total cost of construction being 1,336,400 pounds; it contains two 30,000-kw. units, but there is room for a third set of same output, which it is proposed to erect in 1933–1934; details of coal-handling plant. Nov. 22: Boiler plant; ash-handling and water-softening plant.

The Hams Hall Power Station. Engineer (Lond.), vol. 148, no. 3842, Nov. 8, 1929, pp. 484–487, and 496, 10 figs. Station contains two 30,000 kw. units; there are five Babcock boilers, each capable of evaporating 190,000 lb. per hour from water at temperature of 295 deg. fahr.; each boiler has five "Atritor" pulverizers, each capable of pulverizing 4 tons of coal per hour, and fineness of pulverized fuel is such that 63 per cent will pass through 200 standard-mesh sieve; three-point bleeding has been arranged for; diagrammatic arrangement of closed feed system is shown.

The Portishead Generating Station of the Bristol Corporation. Engineering (Lond.), vol. 128, no. 3331, Nov. 15, 1929, pp. 654–655, 3 figs. partly on p. 624. Station consists of four main sections, viz., boiler house, turbine house, and low-tension and high-tension switch houses, which are built in tiers on hill side; steam-raising equipment consists of four Vickers header straight-tube boilers, supplied by Vickers Boiler Co.; two main turbines were manufactured by Metropolitan-Vickers Electrical Co.; each main generating unit is solidly connected to bank of three 8333-kva. transformers, whereby pressure is stepped up to 33,000 volts for transmission to Bristol.

STEAM-HEATING PLANTS

District, Toronto, Ont. The Toronto Terminals Central Steam Generating Station, J. Breakey. Power House, vol. 23, no. 21, Nov. 1929, pp. 70 and 74–80, 17 figs. Illustrated description of power plant which will be used as supply steam for various purposes in Toronto; boiler equipment; ash handling steam for various purposes in Toronto; boiler equipment; ash handling; draft indicator; layout of boiler room, showing position of boilers, forced-draft fans, water-softening tank, etc.; electric winch; steam flow records; water measurement; feed pumps and generator set.

STEAM POWER PLANTS

Developments in. Scientific Developments in Steam-Driven Power Station Practice, D. Brownlie. Elecn. (Lond.), vol. 103, no. 2683,

Nov. 1, 1929, pp. 525–526. Notes on pulverized-fuel firing; high-pressure boilers; substitutes for water in boilers; low-temperature carbonization; sulphur problem (to be concluded.) Extracts from paper read before Instn. Mech. Engrs.

Fuel Economy. Increased Economy in Thermal Power Station Justifies Increased Initial Costs, A. Baumann. Brown Boveri Rev., vol. 16, no. 11, Nov. 1929, pp. 305–311, 2 figs. It is shown how to determine additional investment costs (per kilowatt installed) which can be justifiably expended on machine (boiler, turbine, generator, condenser, transformer, or auxiliary equipment, etc.) in order to effect saving of 1 per cent in fuel burned in power station; chart for determining additional capital per installed kilowatt and amortization and interest table are given.

Germany. Large Thermal Power Stations in Germany (Les grandes centrales thermiques allemandes), P. Jarrier. Technique Moderne (Paris), vol. 21, no. 16, Aug. 15, 1929, pp. 497–500, 3 figs. Review of present practice is concluded; cheapening of peak-load supply by utilization of water-power storage (natural or pumped) and by means of Ruths' thermal storages; particulars of large turbo-alternator sets and relative merits of alternative arrangements of high- and low-pressure and back-pressure units; back-pressure working is specially advantageous in district heating systems; appendix gives information dealing with high-pressure installations.

Heating and Power. Steam Stand-By and Central Steam Heating Plant of the City of Winnipeg, G. W. Oliver. Engineering (Lond.), vol. 128, no. 3331, Nov. 15, 1929, pp. 609–612, 7 figs. Details of stand-by plant of 11,000 kw. capacity combined with central heating division, utilizing boilers of stand-by plant during winter months; building is divided into four sections, comprising (1) coal-handling and preparation plant; (2) boiler room; (3) turbine room; (4) electric substation, each of which is described.

Power and Process. Power and Process Steam Supplied From Central Station to Paper Mill, W. G. Allen. Power, vol. 70, no. 20, Nov. 12, 1929, pp. 748–752, 4 figs. Description of central power station built by Southeastern Production Co. for purpose of supplying power and process steam to new paper mill of International Paper Co.; initial installation is 6000-kw. 450-lb. turbine arranged for extraction at 150 and 35 lb. and exhausting at 5 lb. back pressure, and 2000-kw. condensing unit; heat-balance diagram for three operation conditions; principal equipment in plant of Southeastern Production Co.

STEAM TURBINES

Bleeder. Tests on a 14,000-kw. Bleeder Turbine (Versuche an einer 14,000 Entnahmeturbine), H. Baer. V.D.I. Zeit. (Berlin), vol. 73, no. 41, Oct. 12, 1929, pp. 1472–1474, 6 figs. Details of double-casing turbine of 20 kva. for supply of superheated steam for lignite drying; plant is of special interest because of arrangement of condenser which is located at one side of turbine; results of acceptance tests.

STEEL

Annealing. Testing of Tempered Steel (Provning av hardat stal), A. Lundgren. Jernkontorets Annaler (Stockholm), no. 8, 1929, pp. 367–374. Communication from State Testing Laboratory on investigation of influence of speed of cooling after annealing on properties of tempered steel and influence of speed of annealing on properties of tempered steel; it is shown that increasing time of annealing increases resistance to bending and impact, but decreases hardness.

Creep. Creep of Steel Under Simple and Compound Stresses, R. W. Bailey. Engineer (Lond.), vol. 148, no. 3853, Nov. 15, 1929, pp. 528–529, 8 figs. Two series of tests are recorded; one was made upon steel tubes strained separately at same temperature by tension and torsion producing equal maximum shear stress; other was made upon lead pipes under internal pressure with superimposed axial loading. Paper read before World Power Conference, Tokio.

Hardness Testing. Recalculation of Hardness Coefficients and Differential Measuring Method for Determining Thickness of Case (Umrechnung von Haerteziffern, etc.), A. Wallichs and H. Schallbroch. Automobiltechnische Zeit. (Berlin), vol. 32, no. 31, Nov. 10, 1929, pp. 712–713, 1 fig. Results of Comparative tests to determine relations of different new hardness-testing values to Brinell number; Herbert's pendulum hardness tester is briefly described and commended and differential method for measuring thickness of case described by E. G. Herbert and P. Whitaker before (British) Iron and Steel Institute is also discussed.

High-Speed, Cutting Qualities. Influence of Composition and Heat Treatment on Properties of High-Speed Steel Used as Cutting Tool (Om sammansattningens och varmebehandlingens inverkan pa snabbstalens egenskaper som skarande), G. Wallquist. Jernkontorets Annaler (Stockholm), no. 7, 1929, pp. 305–350, 41 figs. Results of American, German, and Swedish investigations show that vanadium is best alloy for improving cutting qualities of steel and that difference of 25 deg. cent. from ideal hardening temperature lowers cutting quality 65–86 per cent; ideal annealing temperatures for chromium-tungsten-vanadium high-speed steels and for cobalt steel are given.

Manufacture, Electric Process of. High Quality Steel Is Produced in Electric Furnaces, H. D. Phillips. Foundry, vol. 57, no. 23, Dec. 1, 1929, pp. 997–998. Practice at plant of Empire Steel Casting Co., Reading, Pa. for manufacture of acid steel in electric furnaces is discussed; general method used in manipulation of heats, with special emphasis on deoxidation of slag and removal of practically all of ferrous oxide from slag; 1-in. diameter round gate off green sand casting was bent 90 deg. with sledge hammer.

Strength at High Temperatures. Factors of Safety at High Temperatures. Engineer (Lond.), vol. 148, no. 3852, Nov. 8, 1929, pp. 497–498. Modern demand for apparatus to stand high stresses at high temperatures has introduced considerations which call for re-examination of whole question of factors of safety; for mild steel, such as is used for steam piping, failure will ultimately occur with stress of less than 4 tons per sq. in. if temperature is maintained at 500 deg. cent.; 450 deg. cent. seems to have proved safe temperature with ordinary materials.

Properties of Steels at High Temperatures (Les qualites des aciers à haute température), C. Galatoire-Malegarie. Génie Civil (Paris), vol. 95, no. 16, Oct. 19, 1929, pp. 373–377, 6 figs. Review of recent studies of behavior of special steels at high temperatures and high pressures with special reference to equipment of Issy-les-Moulineaux steam-electric plant; special treatment of steels used; results of tests and operating experience; computation of factor of safety.

The Strength of Steels at High Temperatures. Houdremont and Ehmcke. Metallurgist (Supp. to Engineer, Lond.), Oct. 25, 1929, pp. 155–156, Authors have taken as basis of comparison tensile strength as determined in tests occupying 15 to 20 minutes; considering first lower temperature region, it has been shown that proportionality exists for steels of pearlitic nature between creep strength at 500 deg. cent. and yield point at room temperature.

Working Stresses for Steel at High Temperatures, D. S. Jacobux. Am. Soc. Mech. Engrs.—Advance Paper, no. 22, for mtg. Dec. 2 to 6, 1929, 5 pp., 7 figs. Results of practical experience used for setting maximum working stresses up to temperatures of 800 deg. fahr.; above this, working stresses are scaled down in proportion to falling off of stresses producing creep; first curve of creep points published by J. J. French used and working stresses for given temperature are taken at ⅔ creep-point stress; effect on stress of piercing boiler shell with holes and of transmitting heat through equalization of stress through extension of most-strained fiber.

STOKERS

Traveling-Grate. Tests on High-Power Traveling Grates (Versuche an Hochleistungs-Wanderrosten), H. Presser. Glueckauf (Essen), vol. 65, no. 29, July 20, 1929, pp. 981–991, 11 figs. Construction of Steinmueller traveling grates with subdivided air supply is described, and details given of trials on high-power boilers fitted with grates of this type and burning various fuels; fly-coke problem is discussed; it is concluded that traveling-grate stoker with zonal air supply and no ignition arch is capable of dealing efficiently and at high rates of combustion with wide range of fuels, including fine material of low gas content.

T

TOLERANCES

Skoda vs. D. I. N. System. German and Skoda Tolerances Compared—Discussion, G. Schlesinger and N. N. Sawin. Am. Mach., vol. 71, no. 22, Nov. 28, 1929, pp. 887–889, 3 figs. Reply to discussion of author's article published in Mar. 7 issue of magazine; proof is given that N. N. Sawin's proposal, based rather on point of view that workman should not be trained, than on requirements of interchangeable manufacture, cannot be applied in practice; workman, in applying new medium grade tolerances proposed to three most important classes of fits, may get so many rejections that it must be strongly recommended not to introduce such fits into workshops; data is given on press tests.

TURBO-GENERATORS

110,000-Kw. Ford to Install 110,000 Kw., 1200-Lb. Turbine-Generator. Power Plant Eng., vol. 33, no. 22, Nov. 15, 1929, p. 1219, 1 fig. Description of new vertical compound turbine-generator taking steam at throttle at 1200-lb. gage from two steam-generating units of 700,000 lb. an hour capacity each to be installed at River Rouge Plant, Ford Motor Co.; high-pressure turbine and generator will be mounted directly on top of low-pressure turbine and generator, resulting in most compact unit yet proposed; each element has capacity of 55,000 kw.; 90 per cent power factor, 13,800 v., 1800 r.p.m., 3 phase, 60 cycles, with steam conditions of 1200 lb. gage pressure; 725 deg. fahr. and with 1 in. vacuum.

V

VALVES AND VALVE GEAR

Electric Control. The Hopkinson Electrical Control for Valves. Engineering (Lond.), vol. 128, no. 3331, Nov. 15, 1929, pp. 620–621, 5 figs. Valve forms one of seven being supplied to new Kirkstall Power Station of Leeds Corp.; it is of Hopkinson patent parallel-slide type, 8-in. in diam. and is to operate with steam at working pressure of 490 lb. per sq. in., and temperature of 750 deg. fahr.; motor, of design specially developed for purpose is of three-phase squirrel-cage type with special rotor giving high static torque and having great overload capacity for short period.

W

WAGES

Group-Contract Payment Plans. Applies Group Contract Plan With Success, H. R. Simonds. Iron Trade Rev., vol. 85, no. 20, Nov. 14, 1929, pp. 1248–1249, 1 fig. Group-contract plan for determining wage payment of workers, employed by Spicer Mfg. Co., Pottstown, Pa., is described; each group hires and pays for its own inspector or inspectors, and it is surprising to see how strictly group formen hold their inspectors to care for work.

WASHERS

Lock. A New Type of Lock Washer. Mech. World (Lond.), vol. 86, no. 2233, Oct. 18, 1929, pp. 366–367, 7 figs. Description of new locking principle applied to shakeproof washer manufactured by Barber and Colman, Ltd., Manchester; in two models positive locking action is obtained by twisted teeth that surround external or internal edge of washer; another type particularly used with countersunk-head screws; another type combines locking device with terminal.

WEIRS

Discharge of. Measuring Flow of Water With Sharp-Edged Weirs (Wassermessung mit scharfkantigen Ueberfallwehren), T. Rehbock. V.D.I. Zeit. (Berlin), vol. 73, no. 24, June 15, 1929, pp. 817–823, 5 figs. General review of weir-discharge theories; effect of temperature on velocity distribution in weir nappes; critical review of weir-discharge formulas beginning with Poleni's formula, published in 1767; justification of author's original formula published in 1911 on basis of 280 recent weir-discharge determinations by various investigators; author presents new simplified and more usable form of his original 1911 equation expressing discharge of weirs.

WELDING

Electric. See ELECTRIC WELDING.

WOOD

Testing. Mechanical Properties of Woods and Their Testing (Die Festigkeitseigenschaften der Hoelzer und ihre Pruefung), O. Graf. Maschinenbau (Berlin), vol. 8, no. 19, Oct. 3, 1929, pp. 641–648, 30 figs. Results of recent determinations of tensile and compressive strengths, their variation with moisture content and age; data on buckling strength, strength in shear, resistance to wear and impact; swelling, warping, and shrinkage of woods. Paper read at 1929 annual mtg. of Verein deutscher Ingenieure.

0.6
E J
p.2
R. R.

IN TWO SECTIONS—SECTION TWO

MECHANICAL ENGINEERING

Published by The American Society of Mechanical Engineers, 29 W. 39th St., New York, N. Y.

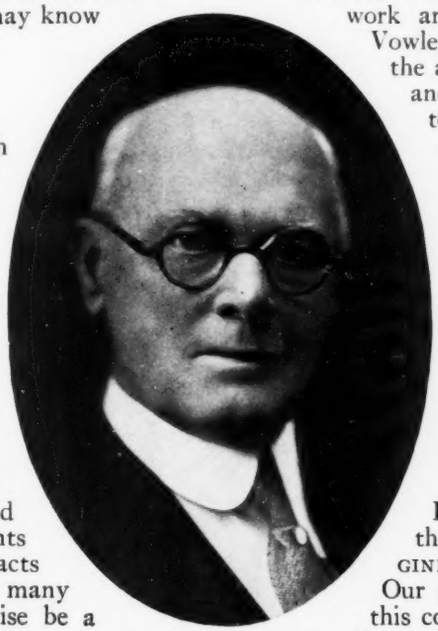
Volume 52 | February, 1930, Section Two | Number 2

What It's All About

REPORTS of progress in research in the thermal properties of steam have been featured in the February issue of MECHANICAL ENGINEERING for several years. Another group of reports and papers dealing with this important subject is published this year. Comment on this and other contributions to the issue is offered in this section so that the hasty reader may know "what it's all about."

A Famous Editor

THERE are many men who owe much to Fred R. Low. Scattered over the land, in engine rooms that form the essential hearts of busy industries, copies of *Power* have found their way; and in moments when all runs smoothly and in the few hours of leisure at home, ambitious youths for forty years have instructed themselves in the details of their duties, and older men have kept abreast with the fast-advancing changes that have taken place in the power plant. Professors in colleges look back upon the men they have trained and take pride in their accomplishments as they take pleasure in personal contacts and recollections. Fred Low's pupils, many of them unknown to him, must likewise be a source of pride and joy to him.



FRED R. LOW, EDITOR EMERITUS OF *Power*

In MECHANICAL ENGINEERING for February notice is taken of Fred Low's retirement from the active editorship of *Power*. He does not retire from the activities of the engineering profession. No man possessing as unique a position as his can so retire. He continues to serve on committees of the A.S.M.E. where his seasoned judgment is always sought. Nor will his direct influence on the readers of *Power* cease, for, as Editor Emeritus, he will continue to contribute a weekly editorial. Meanwhile the journal that has had such a notable influence upon engineers in America continues to carry on the tradition of usefulness which he established for it.

Engineer-Rulers

WHEN class-conscious engineers call attention to Mr. Hoover's professional training and speak of him as an engineer-president, they are apt to create the impression that he is the first statesman possessing such qualifications. Others bring forward the name of George Washington as having been an engineer, basing their assertion on his work as a land surveyor and his connections with engineering projects in city planning and public works. But Mr. Vowles, who contributes an article on "The Engineer as Ruler" to the February issue of MECHANICAL ENGINEERING, goes back farther still to Gudea, of Sumeria, governor of Babylonia in 2600 B.C.

The justifiable pride with which engineers view the elevation of one of their number to the high estate of Presidency of the United States of America is based on their conviction that the engineer's habits of thought and work are productive and efficient. Thus Mr. Vowles, an Englishman, is led to comment on the appropriateness of the engineer as ruler, and to call attention, once more, to that interesting character Gudea who lived so many centuries ago and who ruled so vigorously and so constructively.

Economic Changes

THE so-called Hoover report on recent economic changes has been widely read and discussed. The secretary of the Committee on Recent Economic Changes of the President's Conference on Unemployment, Edward Eyre Hunt, of the U. S. Department of Commerce, addressed the Annual Meeting of the A.S.M.E. last December. His address is published in the February issue of MECHANICAL ENGINEERING.

Our problem, he points out, is to develop in this country a technique of economic balance. We are far from possessing such a balance, he says, and we must know far more than we do now, but a sound beginning has been made. "Already the swings of our economic seesaw are notably less than they were before the war. We shall never know how much more they can be controlled before we try."

Steam Research Today

THE February issue of MECHANICAL ENGINEERING contains additional reports on progress in steam research covering the year 1929. About nine years ago, with the increased use of higher steam pressures, designers found that they could not rely upon the accuracy of available tabulations of the thermal properties of steam in the higher regions. Most of the research had been done at lower pressures and various extrapolations were made by students of the data who proposed formulations based on the best evidence obtainable. A group of research workers at Harvard, M.I.T., and the U. S. Bureau of Standards therefore cooperated under the auspices of the A.S.M.E., and with the help of the engineering industries extended experimental knowledge of the important properties into the region of the critical pressure. Last year progress

was made by the presentation of a revised Mollier diagram prepared by Prof. J. H. Keenan and published in MECHANICAL ENGINEERING. This year additional data are reported by the investigators, and the announcement is made that tabulated values of the data which formed the basis of the chart have been computed by Professor Keenan and are shortly to be available as a tentative steam table. Until closer agreement between investigators in various countries can be secured, and until their research programs can be completed, these tables will offer the most reliable data extant in this country.

The group of reports includes that of the technical sub-committee by its chairman, Geo. A. Orrok, the work of Keyes and Smith of M.I.T., that of Osborne, Stimson, and Fiock of the U. S. Bureau of Standards, as well as the report of the international conference held in London last July. This conference brought together most of the principal researchers in steam in England, Germany, Czechoslovakia, and the United States of America. Aside from establishing closer relations between these investigators in a problem of common interest, the conference agreed upon a network of fixed points in the saturated and superheated regions. At each of these points there is not only an agreed-upon value of volume and total heat, but also an agreed-upon tolerance or measure of uncertainty. It was agreed that if at each of these test points any present table lies closer than the selected tolerance to the selected value, then the table is, for the present at least, an international table. Surely this is progress!

With these reports there is also a contribution in the form of "Notes on Formulation," by Prof. R. C. H. Heck, of Rutgers. This presents, first, an investigation of the pressure-volume form of the adiabatic of steam, leading to a general comparison of formulations, and second, a discussion of the thermal properties of the liquid along and behind the saturation line.

George Patten, A.R.A. pinx. 1863 — Imp. Wittmann, Paris. — H. Manesse sc.

2nd That the quantity of heat capable of increasing the temperature of a lb of water (weighed in vacuo, and taken at a temperature between 55° and 60°) by one degree Fahr., requires for its evolution the expenditure of a mechanical force represented by the pressure of 772 lbs. through the space of one foot.

J. P. Joule

[From "Memoir of James Prescott Joule," by Osborne Reynolds, Manchester, England, 1892.]

Early Researchers in Steam

AS RESEARCHES in the thermal properties of steam progress to a point where reliable tables extending beyond the critical region seem to be a possibility of the near future, it is well to remember that the problem is a relatively old one. Starting with the practical development of the steam engine by Watt and continuing throughout more than one hundred and fifty years of improving technique in scientific research and greater need for accurate data by designers, the search for the true properties of steam has occupied the attention of many scientists and engineers. The group of delegates to the International Conference on the Steam Tables held in London last summer, pictured on the cover of MECHANICAL ENGINEERING for February, contained many of the present workers in this field in England, Germany, Czechoslovakia, and the United States of America. Above this group the portraits of Joseph Black, James Watt, and Henri Victor Regnault bear witness to the influence and contributions of these men in the development of this branch of research.

Joseph Black and James Watt were intimate friends, Black a chemist and Watt an instrument maker and inventor. It is to Black that we owe the ideas of latent heat and specific heat. Observing how substances gained and lost heat without change in temperature while in states of fusion and vaporization, he coined the expression "latent heat" to describe the phenomenon. Additions of different substances such as mercury and water in known amounts and temperatures, he noted, had altogether different effects upon raising the temperature of water with which they were mixed, so that he was led to the belief that a given mass of one substance did not necessarily have the same heat capacity as that of another substance. Thus he established the conception of specific heat.

Working during the same period, Watt also made determinations of the latent and total heats of water and of the pressure-temperature relation of saturated steam. Due to the lack of precision in his apparatus, Watt believed that the total heat of steam was constant at all pressures. For years this so-called Watt's law was held to be true. Another contemporary, J. Southern, in 1803, experimenting in the same field, questioned Watt's law, believing that it was the latent heat which remained constant. Watt also writes of having determined and plotted the relation between the pressure and temperature of steam "and thereby found the law by which they were governed, sufficiently near for my then purpose."

Other early investigators of the pressure-temperature relation were Ziegler (1769), Betancourt (1790), Volta (1793), Robinson (1796), Dalton (1801), Gay-Lussac, Ure (1818), Despretz (1819), Prony, Girard, and Dulong, members of the Commission of the Academy of Paris (1829), the Committee of The Franklin Institute of Pennsylvania (1836), Gustav Magnus (1844), and Regnault (1844).

Of these early researchers in steam, Henri Victor Regnault, the French physicist and chemist, who published his "Elastic Forces of Aqueous Vapour" in 1844, deserves the most conspicuous mention. His researches were so carefully made that Robert W. Dixon, writing about Regnault's table in 1849, says: "There can be little doubt that the experiments on which those tables are based are the most accurate which have hitherto been made in reference to this subject, and it is probable that a considerable time will elapse before a similar series will be undertaken by an experimenter combining so much acquired skill and natural aptitude for physical investigation, with the facilities and advantages that M. Regnault had at his command."

The tables referred to, as computed in English units, give the "elastic force of aqueous vapours from —30° to 432° Fahr." Regnault also derived the well-known formula for the total heat of saturated steam, above 32 deg. fahr., in terms of its temperature as $H = 1091.7 + 0.305(t - 32)$, an expression quoted in Kent's Handbook as late as 1909.

The Passing of "J"

ONE of the dramatic incidents in the progress of science in the 19th century was the reading of a paper before the British Association in Cork in 1843 when Joule presented his first determination of the mechanical equivalent of heat. Recently weaned from the phlogiston theory of heat and still dallying with that of the imponderable fluid caloric, scientists hesitated to accept Joule's evidence. As Joule himself says, "the subject did not excite much general attention." Later, before the Association in Oxford in 1847, he again presented his theory—orally, because of lack of time for fuller reading. "The communication," he says, "would have passed without comment if a young man had not arisen in the Section and created a lively interest in the new theory." The young man was William Thomson, later Lord Kelvin. Thomson, while impressed with Joule's experimental evidence, declared, in 1848, that "the conversion of heat into work is probably impossible, certainly undiscovered." Three years later, however, he based his famous paper on "The Dynamic Theory of Heat" on Joule's experiment and on the work of Carnot and Clausius.

Joule naturally related two fundamental units of energy, the mechanical unit, or foot-pound, and the British thermal unit, which was based on the thermal capacity of water. From his experiments he showed that 772 ft-lb. of mechanical work was the equivalent of one B.t.u. Once the significance of this constant equivalence was established, the exact determination of the conversion factor J became an important task for scientists, and increasingly more precise values of the factor have been made from time to time.

In a paper on "The Passing of the Mechanical Equivalent of Heat," E. F. Mueller, of the Bureau of Standards, calls attention to the acceptance by the International Steam Table Conference of the kilocalorie as a heat unit defined as the heat equivalent of one international kilowatt-hour divided by 860. Defining the heat unit in electrical terms obviates the necessity for two independently determined units of energy and also for a conversion factor whose value is subject to change with every more precise measurement of the thermal capacity of water.

Thus while Joule's mechanical equivalent of heat becomes of less fundamental interest to scientists, the principle which he established, that energy can be measured in various ways, becomes even more significant with the definition of the heat unit in electrical terms.

Fifty Years Old

IN APRIL of this year The American Society of Mechanical Engineers celebrates its fiftieth anniversary. Appropriate anniversary ceremonies will be observed at the Society's headquarters in New York, at the offices of the *American Machinist*, where the project of founding the Society was first discussed, at the Stevens Institute of Technology, Hoboken, where the first meeting was held, and in Washington. Here the celebration will assume an international aspect by the presentation, by sixteen foreign delegates, of addresses describing the economic and social features of engineering in their respective countries.

Because of this important birthday, the April issue of MECHANICAL ENGINEERING will be an anniversary number devoted to special features. All regular departments will be omitted. The contents will be historical and biographical in character, featuring the A.S.M.E., the men who have been its presidents and honorary members, and the technical developments in the field of mechanical engineering since 1880.

Because of the permanent value of the historical and biographical material published in the anniversary issue, copies of the text pages are to be separately bound with some of the addresses delivered during the celebration and an account of the meetings which are planned. These books will be offered for sale at a price merely sufficient to cover the costs involved.

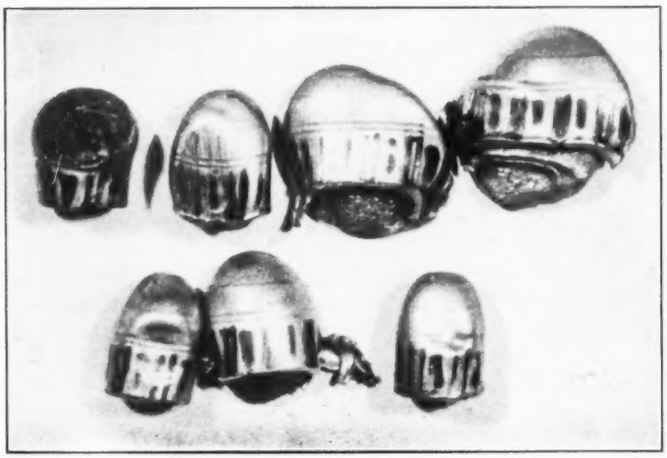
Tell-Tale Marks on Bullets

THE gruesome exhibit illustrated on the following page —of machine-gun bullets taken from the body of a slain gangster—shows how, even when distorted by mushrooming, the steel jackets still retain the marks made on them in passing through the barrel of the gun. Studied under the microscope, characteristic striations on the bullets can be detected by experts. They are caused by peculiarities of the gun from which the bullets were fired, and serve as a means for identifying the fatal weapon. To Calvin Goddard and Associates we are indebted for the picture.

Some of the fundamentals involved in the identification of firearms from the marks on the bullets fired from them are discussed by Major Charles O. Gunther in an article in the February issue of MECHANICAL ENGINEERING entitled "Markings on Bullets and Shells Fired From Small Arms."

Major Gunther analyzes the motion of a bullet passing through the bore of an automatic pistol. He discusses the force required to drive the bullet through the bore and the characteristics, peculiar to the bore, by which the bullet fired through it can be identified. How the marks made on the surface of the bullet by the lands and grooves of the

bore can be interpreted is also explained. In conclusion, it is shown how characteristic imprints of the breech block and firing pin on shells and primers offer a means of identification when ejected cartridges are found.



TELL-TALE MARKINGS ON BULLETS FROM THE BODY OF A SLAIN GANGSTER

(Photograph loaned by Calvin Goddard and Associates.)

The identification of firearms from marks on the bullets and shells is not yet the exact science that the Bertillon system based on fingerprinting has become. It has, however, had an important influence in the acquittal and conviction of suspects in murder trials.

The Engineering Index Service

THE December, 1929, issue of this section of MECHANICAL ENGINEERING gave a brief description of The Engineering Index Service of the A.S.M.E. Since the beginning of the year, the Index Service has issued a circular announcing a revision of its subject classifications and a reduction in rates.

The new circular lists 223 separate divisions, each of which is devoted to an engineering subject. A carefully worded description of what is, and in some cases what is not, included in each division is given, as well as the price of the service for that division for one year. Prices are based on the number of references which the experience of two years indicates have been indexed, and range from seven to sixty dollars. The complete service—over 46,000 individual cards last year—is now available at $1500.

The subscriber may now make up his own list of divisions from the new classification and subscribe to from 1 to 223 of the divisions according to the breadth of his interests and needs. A subject index makes it possible to determine easily in what division of the service a specific subject is classified. To illustrate: An engineer, interested in feedwater treatment is referred by the subject index to Division 97, where he finds the following description:

97. INDUSTRIAL WATER TREATMENT

Boiler and locomotive feedwater treatment, boiler scale prevention, boiler corrosion, treatment of water for manufacturing processes. (See No. 217 for potable water treatment.)..$9.00

Engineers at Washington

IS UNCLE SAM a good employer?

Following the approved engineering method of making a study of the facts before drawing any conclusions, the Washington Section of the A.S.M.E. has investigated this question. The results of the investigation are presented in the February issue of MECHANICAL ENGINEERING in an abstract of a report. The economic status of technically trained employees in all branches of the Federal service in the District of Columbia is covered by the report. The following are the conclusions:

1 Salaries of Federal engineers should be made commensurate with duties and responsibilities and at least equal to those paid engineers outside Federal service.

2 There should be no "average of the grade" restriction limiting promotion within the grade.

3 Retirement annuities should be sufficient to maintain employees in comfort and at least equal to those paid by the larger industrial organizations.

Fluid-Film Lubrication

A TYPICAL large turbo-generator having a shaft 21 in. in diameter, has three bearings and a coupling which occupy a total length of 18 ft., as compared with 14 ft., which is the useful part of the generator between bearings. This in part explains what A. G. M. Michell, in a paper entitled "Progress in Fluid-Film Lubrication" in the February issue of MECHANICAL ENGINEERING, means when he says that "to the designer, all bearings are only necessary evils."

Mr. Michell, designer of the "crankless" engine in which his principle of bearing construction is utilized, has applied the hydrodynamical theory of lubrication to thrust bearings, and believes that a general reformation of journal bearings is long overdue.

Mr. Michell developed the thrust bearing in Australia while Albert Kingsbury was developing it simultaneously in this country along similar lines. By the establishment of a wedge-shaped film of lubricant between the bearing surfaces, metallic contact is broken and the moving load is supported on an oil film, making possible greater bearing pressures and hence a reduction in bearing size.

KEY TO PHOTOGRAPH OF DELEGATES TO INTERNATIONAL STEAM-TABLE CONFERENCE ON FRONT COVER OF "MECHANICAL ENGINEERING" FOR FEBRUARY

Top row: H. C. Dickinson, W. H. Patchell, S. J. Davies, D. V. Onslow, N. S. Osborne, J. H. Keenan, G. Stoney
Middle row: E. B. Wedmore, Geo. A. Orrok, H. Hausen, L. Mišković, B. Pochobradsky, M. Jakob, W. Koch, I. V. Robinson, R. Mollier
Bottom row: Harvey N. Davis, H. L. Callendar, F. Samuelson, J. Havliček, O. Knoblauch